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Forecasting Research

Forecasting Research Division
Technical Report No. 132

Revised Moisture Assimilation - Results of a parallel trial

by

R.S. Bell

November 1994

Meteorological Office
London Road
Bracknell
Berkshire
RG12 2SZ
United Kingdom

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1. Introduction

The background to this problem and details of the revised scheme together with results from some preliminary experiments is given in Bell (1994). Briefly the change is intended to eliminate the so-called 'spin-up' in cloud and rainfall during the first 12 hours of a forecast. The proposed change contains two components:

(i) conservation of RH during the updating of temperature fields within the assimilation step, such that no 'drying' occurs when the observations 'correct' for the model's cold bias.

(ii) a revision to the preprocessing of radiosonde RH profiles. The interpolation from observation points to model layers is done as a simple linear interpolation to mid-point of layer rather than attempting a layer average. This reduces the tendency of to smooth out ex treme moist (or dry) layers in the profile. Additionally, the relative humidity in the interpolated report is boosted near saturation to counter the reported dry bias in the instrument itself. The boost is taken as

$$
\begin{aligned}
\Delta RH &= 0 && \text{for } RH_{ob} < RH_{crit} \\
\Delta RH &= (RH_{ob}-RH_{crit})/(90-RH_{crit})*4.6\% && \text{for } RH_{crit} < RH_{ob} < 90 \\
\Delta RH &= 4.6\% && \text{for } 90 < RH_{ob} < 95 \\
\Delta RH &= (100-RH_{ob})/(100-95)*4.6\% && \text{for } 95 < RH_{ob} < 100 \\
\Delta RH &= 0 && \text{for } RH_{ob} = 100
\end{aligned}
\qquad (1)
$$

Maycock and Macperson (1994) have determined that the revised profiles when fed through the model's cloud algorithm generate cloud amounts which are consistent with the surface report collocated with the radiosonde. They found that the size of the boost was a function of model resolution (a representivity effect) and the values given above form the LAM are different to those applicable to the mesoscale configuration.

The change was implemented into the UK Mesoscale configuration of the UM alongside a package of other changes in September 1994 after successful offline tests.

This paper documents the results of a parallel trial of the moisture assimilation changes which ran from 4th to 21st October 1994. A revised continuous global assimilation was run with a forecast to T+72 from 12Z. This forecast generated the boundaries for a 4 cycle revised LAM assimilation (15Z,18Z,21Z,00Z) leading to a LAM forecast from 00Z data time.

2. Impact on Spin-Up

2.1 Global area mean rain

Figure 1 shows three timeseries of global mean rain rates as a function of forecast period. The top plot compares the trial and operational 12z analyses. We see global mean rates of 2.32 mm/day from the operational system, compared to a more respectable 2.63 mm/day from the trial. The middle plot shows the same analysed rain rate from the operational runs together with the equivalent forecast values from each run (at T+24, T+48 and T+72). It is clear that the analysis plot belongs to a different population. The bottom plot shows the same forecast trend for the trial. Here the analysis plot is bunched together with the three

forecast plots. Although there is still a tendency for increasing rainfall through the forecast period, the 'spin-up' is clearly much reduced. It is not clear now whether the remaining spinup is due to an analysis deficit in rain or the forecast having excessive rain. In fact the trial has slightly less rain than the operational run beyond the first day (2.78, 2.87, 3.00) compared to (2.84, 2.94, 3.08) at T+24,48,72 respectively. This difference is entirely convective. It is probable that the warming is stabilising the trial.

2.2 Global area mean cloud

Figure 2 compares the timeseries of analysed global mean cloud cover. In all three plots for high, medium and low cloud, the trial runs are substantial cloudier than the operational runs. The biggest difference is for high cloud, with the mean cover increasing from 21.7% to 25.6%. The % cover in the trial analyses is much closer to the T+24 and T+48 forecast means (27.2 and 28.1 respectively in the trial runs)

2.3 Average LAM area mean rain and cloud

Figure 3 gives the area averaged mean rain rate and mean cloud as a function of forecast period. The meaning is over all forecasts from 6th - 20th October. The top plot shows the rain rates. The trial is clearly wetter in the first 18 hours. As in the global model, the LAM spin-up is much reduced. There still appears to be a significant spinup in the first 6 hours, but the diurnal effects make this appear to exaggerate it, since the slope between T+24 and T+30 is almost as large as between T+0 and T+6 in the trial results. The lower three plots give similar comparisons for high, medium and low cloud respectively. The conclusions drawn from the rain plot apply equally to the cloud plots.

3. Objective verification

3.1 Global Analysis and Forecast against Observations (sonde and synop)

Figure 4 contains a table which summarises the objective scores for the Northern Hemisphere. Results for both 'Area 2' and 'Area 200' are included at 4 periods (T+0, T+24, T+48 and T+72). 7 levels are verified for the height, temperature and wind fields, plus 3 moisture levels and 2 surface fields. The comparison is presented in terms of the ratio of (trial rms score)/(operational rms score) scaled by 100. Thus numbers below 100 imply an improvement and the difference from 100 indicates the percentage change in rms score. Changes in excess of 1% are highlighted.

The height scores are improved 3-4% at T+24 and T+48, particularly in the middle and upper troposphere. This result from a 1-2% improvement in temperature scores. Wind scores are unchanged. The humidity scores are improved by 3-4% at analysis time but this improvement is not sustained at T+24 and beyond. There are no significant degradation in any scores.

Figure 5 gives exactly the same results except that the areas are the tropics (Area 300) and the Southern Hemisphere (Area 400). The improvement in the tropical height and temperature scores is marginally larger than in the northern hemisphere, with some scores improving by as much as 6%. In the southern hemisphere with very much less observations

to verify, we see less evidence of a positive signal. The signal is a slight negative at T+24 for winds and more generally at T+72, by around 1-2% peaking at 4% for T+24 uper winds.

The table below summarises the information in figures 4 and 5 in terms of the number of scores improved (by in excess of 1%) or degraded (ny in excess of 1%) in each area. With 4 periods and 26 fields, we have 104 scores per area. We see the positive signals far outweighing the negative signals except in the Southern Hemisphere.

Area	Trial Better	Scores 'Same'	Trial Worse
N Atlantic (2)	28	70	6
N Hem(200)	20	84	0
Tropics(300)	32	55	17
S Hem (400)	12	60	32

Table 1: Summary of scores contained within figures 4 and 5

Figure 6 presents the Area 200 scores for temperature graphically. The pecked line show the trial scores and the solid lines show the operational scores. The upper two plots are T+0 (mean errors on the left and rms errors on the right), below these are T+24, with T+48 scores at the bottom. These plots demonstrate that one contribution to the improvement in rms results is the decrease in the cold bias. This is due primarily to the additional latent heating following the increase in precipitation. In the middle to upper troposphere the bias is reduced by about a third.

Figure 7 shows the similar 6 plots for the height mean and rms scores at T+0, 24 and 48. Here we see an increasing improvement in the mean error as one looks to the higher levels.

Verification against analyses were only briefly examined. Given that each forecast was verified against its own analyses which are of course different, the results (not shown) are less valid than the verification against observations. In the northern hemisphere areas (2 and 200), similar trend were noted. Only 1 score out of 64 was 'worse' in each area, whilst half the scores were 'better'. The signals in the tropics and southern hemisphere were reversed compared with verification against observation, with more 'worse' than 'better' in the tropics and an overall neutral signal in the southern hemisphere. The poor southern hemisphere 250hPa wind score at T+24 (4% worse) was less noticable in the analysis verification (2% worse).

3.2 LAM Analysis and Forecast against Observations (sonde and synop)

Figure 8 shows rms comparison for the LAM runs, similar to figures 4 and 5 but only for periods T+0 and 24. The two areas are the UK area (area 5) and the larger domain (area 88). The results support the improvement noted in the global area 2 comparison. In fact the UK scores are improved by an even bigger margin with upper tropospheric height scores

improved by 8% at T+24. T+24 temperature scores are improved by up to 4% and T+0 humidity scores by up to 6%. This larger improvement might be due to the correction to UK sonde humidities which were noted as being a particular problem. In the larger areas, the effect of the change is diluted because the sonde coverage is rather localised.

Of the 96 scores contained within the table in figure 8, 30 show the trial to be giving an improvement in excess of 1% and only 9 show the trial to be worse by in excess of 1%.

Figure 9 presents the LAM T+24 objective scores graphically. The pecked lines show the trial scores and the solid lines show the operational scores. The upper two plots are for temperature (with mean errors on the left and rms errors on the right for Area 5 followed by Area 88), below these are the equivalent height scores. The signal is similar to that from the global model (shown in figures 6 and 7)

3.3 LAM Rainfall against synops

Objective rainfall verification was available from the last 10 LAM forecasts. The results are not very reliable since the period was unusually dry. Within the UK domain, the observations indicated dry conditions on 82 - 87% of the 6 hour periods (the range indicating the diurnal variation). The larger European area was even drier with 88 - 91% of the reports being dry.

The table below summarises the results (best results identified by bold figures) . The improvement in the objective scores in the first 12 hours is clear enough, interms of bias and hit rate but not % correct. Beyond then the signal is rather mixed with perhaps the operational run being slightly favoured at the later stages. The subjective validation against radar data presented in section 4.1 is much more clearly in favour of the trial. Given that we would not attempt a subjective assessment against synop data, I wonder how valid the objective assessment is? Consideration should be given to adaption of the MOPS rainfall verification to other configurations.

	Bias		% Correct (Y/N)		Hit rate (%)	
	Trial	Oper	Trial	Oper	Trial	Oper
0-6	**0.8**	0.6	84	**86**	**47**	40
6-12	1.5	**1.4**	86	**88**	**79**	78
12-18	1.9	1.9	81	81	77	**78**
18-24	1.3	1.3	85	85	55	**59**
24-30	1.4	**1.3**	77	**78**	**59**	54
30-36	2.0	**1.9**	77	**78**	71	71

Table 2: Summary of LAM rainfall verification

4. Subjective verification of LAM

Frontiers radar data was saved on the FR workstation system at 6 hour intervals from 7th through to 21st (aside from a few gaps due to software problems). Given the (i) lack of rain: and (ii) the need to generate validation promptly, the validation will concentrate on the period where the verifying data is readily available.

Similarly satellite data was saved from the 11th through to the 21st (mostly 6 hourly for IR and 12Z only for VIS). The validation of cloud concentrates on this period. The cloud verification charts are space views without lat-long lines overlaid, which makes validation difficult in the Atlantic.

The evolution of pmsl was very similar. No significant changes were noted and it will not be considered further.

All the figures relating to the following two sections contain the validation above the pairs of forecast charts. The operational charts are lower left and the trial charts are lower right. Note that on the trial rain rate charts, the snow lines are missing because the relevant fields were omitted from the trial fieldsfile.

4.1 Rainfall forecasts verified against Frontiers

Most differences of significance were restricted to the period T+0 to T+12, although one major difference was noted beyond T+24.

4th-6th Were not considered as the verification was not readily available.

7th Very similar forecasts for UK with old front over Southern Scotland dying out during first 12 hours of forecast. The trial had more rain from that front over the North Sea at T+6 which could not be verified.

8th The T+6 forecasts with verification are given in **Figure 10**. Another weakening front is moving south, into the Midlands. The operational run has no rain over England and Wales, whereas the trial has a good representation of the rain observed by the radar network.

9th Correctly dry everywhere in both runs.

10th **Figure 11** shows T+30 forecasts with verification. On the morning of the 11th, an area of rain was moving north and east from France. At 6z the operational forecast had a large area of dynamic rain covering all of Southern England as far north as Oxford with 6 hour accumulations as high as 10mm on the coast. In contrast the trial had showers in the counties bordering the Channel with a few lighter showers in a band towards South Wales. Accumulations in the 6 hour period to 6z were no more than 3mm. The radar shows the operational run to have been completely misleading. The same rain area over France in the following day's forecast was very much weaker in the operational analysis (00z 11th) compared with the trial analysis.

12th-14th Correctly dry everywhere in both runs.

15th The forecasts were similar. **Figure 12** shows the rain at analysis time. The rain band over Northern Ireland and Scotland is too weak in the operational run and rather better in the trial, although both runs seem rather slow over Scotland.

16th On the 16th there were two areas of interest. **Figure 13** shows both 00z and 06z radar

plots and the T+6 forecast accumulations 00-06z. Showers in the Channel were missed in the operational run. The trial had these and also an indication of some precipitation in the South East, which as I recall was correct as the ground was wet first thing Sunday morning in Bracknell. The operational run is also deficient over Northern England and Northern Ireland. The radar shows a larger area of rain at midnight diminishing rapidly by 06z. This is much better predicted by the trial.

17th Correctly dry everywhere in both runs.

18th Was not considered as the verification was not readily available.

19th Both forecasts were poor as far as the South East was concerned. The rain predicted for the afternoon was not very substantial (This was the day of the October Met Soc meeting an I expected to get wet!). **Figure 14** shows the trial is slightly better at 12z (T+12), with the rain being one grid row further back towards the SW.

20th **Figure 15** shows a continuous band of rain running up the East side of the country at 06z with showers to the south and west. By 12z (not shown), these showers had penetrated inland into Central Southern England. Both T+6 and T+12 forecasts are shown. At 06z, we see a large gap in the rain band depicted by the operational forecast (from Edinburgh to the Wash!), whilst the trial the trial has at least got 6 shower symbols partly filling that gap. At 12z, the trial has a better indication of the shower distribution in the south.

21st Not much difference over the UK, but the radars showed a rain band to the East over the North Sea. The trial run correctly had rain further south than the operational run. The cloud validation in the subsequent section confirms this.

4.2 Cloud against Meteosat

As a generally point, I noted that there seemed to be too little low cloud over the sea in both runs compared with the 12z visible image, particularly in the anticyclones.

4th-10th Were not considered as the verification was not readily available.

11th **Figure 16** shows the T+12 forecasts together with the visible image for validation. The feature to note is the double cloud band between Scotland and Norway with the southern band through Northern Scotland and into the Atlantic to the north of Ireland. The trial run appears to have captured these features much better than the operational run.

12th **Figure 17** shows the T+12 forecasts together with the visible image for validation. The main differences here are (i) the more continuous band of low and medium level cloud between Iceland and Norway; and (ii) the low cloud on the Dutch and Germ an coasts, in the trial run compared with the operational run. The former is not obviously correct in the trial when one looks at the visible image alone, but the IR image (not shown) identifies a continuous band of colder cloud. The latter is clearly correct in the trial, the validation in fact shows a continuous band from the Baltic States to East Anglia.

13th No significant differences were noted on the this day.

14th **Figure 18** shows the T+12 forecasts together with the visible image for validation. The main point to note is the low cloud band from East Anglia to Denmark is more extensive in the trial and correctly extends several degrees further west into Lincolnshire.

15th No significant differences were noted on which could be easily verified.

16th **Figure 19** shows the T+12 forecasts together with the visible image for validation. The trial is probably correct in having more cloud in the North.The bands of cloud in the Atlantic to the west of France also look more realistic in the trial.

17th **Figure 20** shows much more cloud in the trial analysis to the east of the trailing front in Mid-Atlantic; (This shows as medium cloud in the north and low cloud further south). The IR image was unclear but seems to show large amounts of low cloud in that area. This case probably demonstrates the impact of conserving RH during the temperature assimilation, since it is unlikely that radiosonde RH assimilation would have an impact in that area.

18th No cloud validation was readily available.

19th-20th The cloud signal confirmed that noted in the rainfall comparisons above.

21st **Figure 21** shows the analyses together with the IR image for validation. The main point to note is the amount of cloud in the North Sea which is much better depicted in the trial analysis.

4.3 Model Analysis Tephigrams against radiosondes

The improved analysis of cloud and rain is due in part to the better representation by the analysis of the moist layers identified by the radiosondes. This was of course one component of the change. In **Figure 22**, we illustrate this by showing several model ascents (collocated with Lerwick) from both trial (righthand plots)and operational (lefthand plots) analyses. The upper two plots are for the 8th. Here we see the trial analysis is saturated through two levels, whereas the operational run remains unsaturated. There is good reason to believe that the t rial was better. The radiosonde was reporting 97% at 850hPa and the operational processed layer averaged value for model level 5 was 98%. The lower two plots are for the 13th. Here the trial is saturated at only one level. The radiosonde was reporting in excess of 99% at 925hPa with very much drier air above.

5. Impact on soil moisture

In the second week of the trial the soil moisture field was allowed to evolve freely. It was difficult to obtain a meaningful signal from the soil moisture evolution in such a short period. Because the operational soil moisture field was being reset to climatology on a daily basis, no meaningful comparison of the impact of the assimilation changes on the freely evolving soil moisture field could be made. We did note that as a global average, there was still a drying in assimilation mode relative to forecast mode, but only longer runs would identify if this was excessive. It was also noted that some areas were considerably wetter than climatology (eg. Texas where considerable rainfall had occurred during the period). A longer offline assimilation is planned.

6. Conclusion

In summary, the benefits include:

a) Better cloud analyses and forecasts for the majority of cases (at least to T+12)

b) Better rainrate analyses and forecasts for the majority of cases (at least to T+12)

c) Occasional significant improvement in rain forecast at longer range. One case in 14

d) Reduction in cold bias by up to a third in the mid and upper troposphere, with consequential reduction in height bias.

e) Spin-up of moisture fields almost eliminated.
f) Reduction in rms scores for height (by up to 8%) and temperature (by up to 4%) in LAM at T+24
g) Reduction in rms scores for height and temperature in global model (both northern hemisphere and tropics) at T+24 and T+48
h) Better fit of RH analysis to observations, as demonstrated by model ascents at radiosonde locations and by the rms scores.
i) Possibility that the model evolution of soil moisture might be better than climatology (more investigation needed)

Several less positive points should be noted:
a) The objective scores for the southern hemisphere favour the operational runs, with a 1 or 2% increase in rms at T+72; as well as an increase of 4% at T+24 for upper winds.
b) The clear signal in the subjective assessment showing substantial benefits is not fully reflected in the objective rainfall scores.

The positive points clearly outweigh the negative points and it is recommended that the change be implemented.

It is further recommended that a rainfall validation scheme based on the radar data be adopted for the LAM.

Acknowledgements

Dale Barker, Bruce Ingleby, Adam Maycock and Bruce Macpherson (FR) contributed to the debate on the radiosonde moisture bias problem.

References

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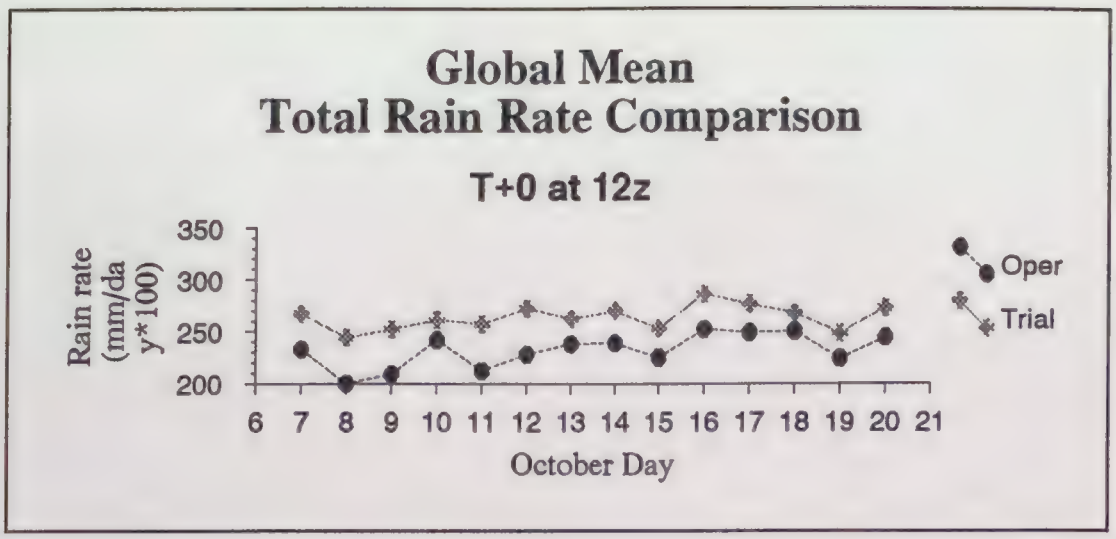
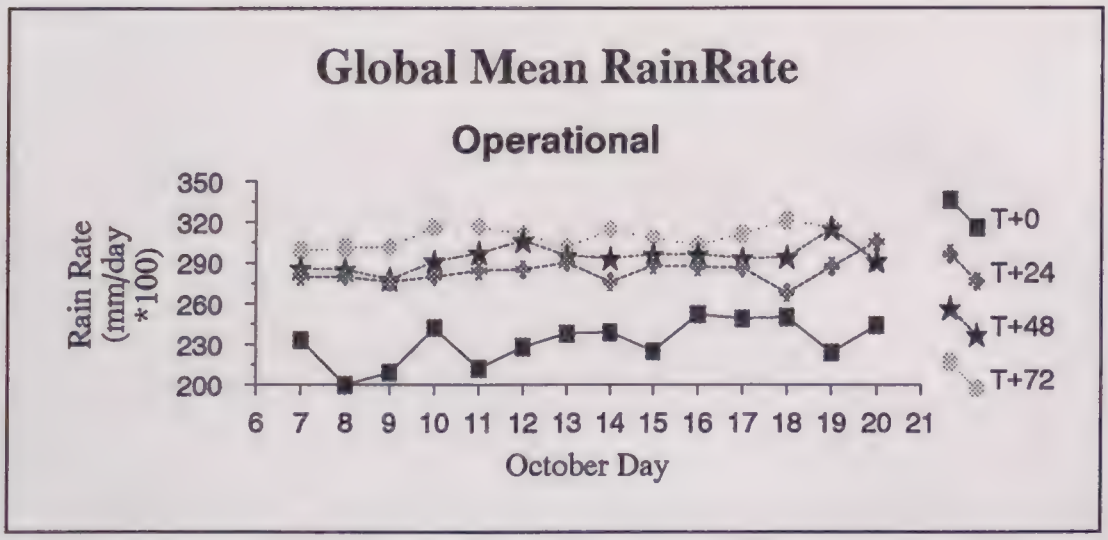
Maycock AJ and Macpherson B, 1994, 'Developments in mesoscale data assimilation at the UK Met Office, proc 10th AMS conf on NWP, Portland, pp 561-563


Global Mean
Total Rain Rate Comparison
T+0 at 12z
Rain rate (mm/da y*100)
350
300
250
200
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
October Day
Oper
Trial


Global Mean RainRate
Operational
Rain Rate (mm/day *100)
350
320
290
260
230
200
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
October Day
T+0
T+24
T+48
T+72

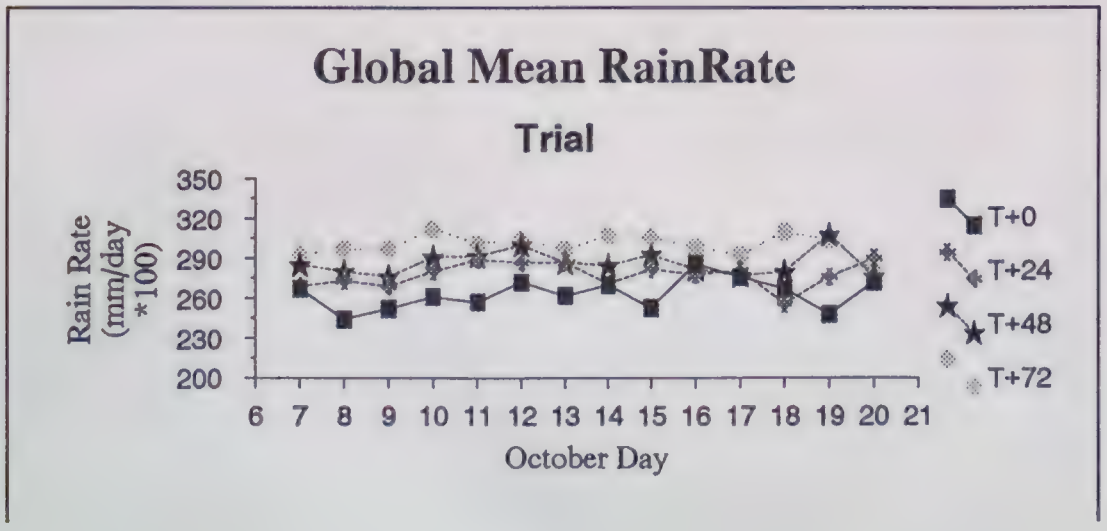
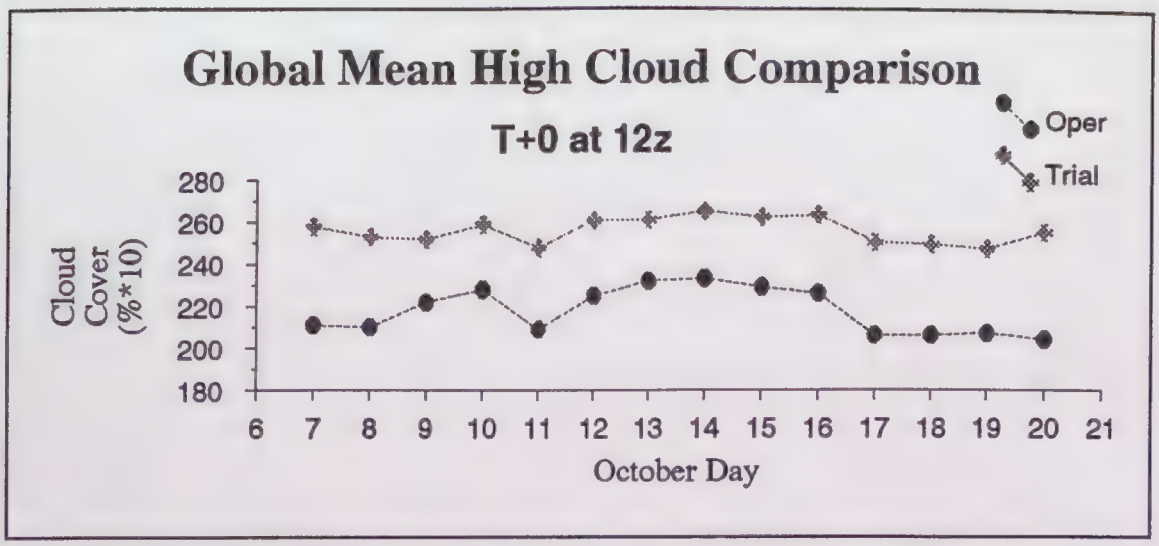
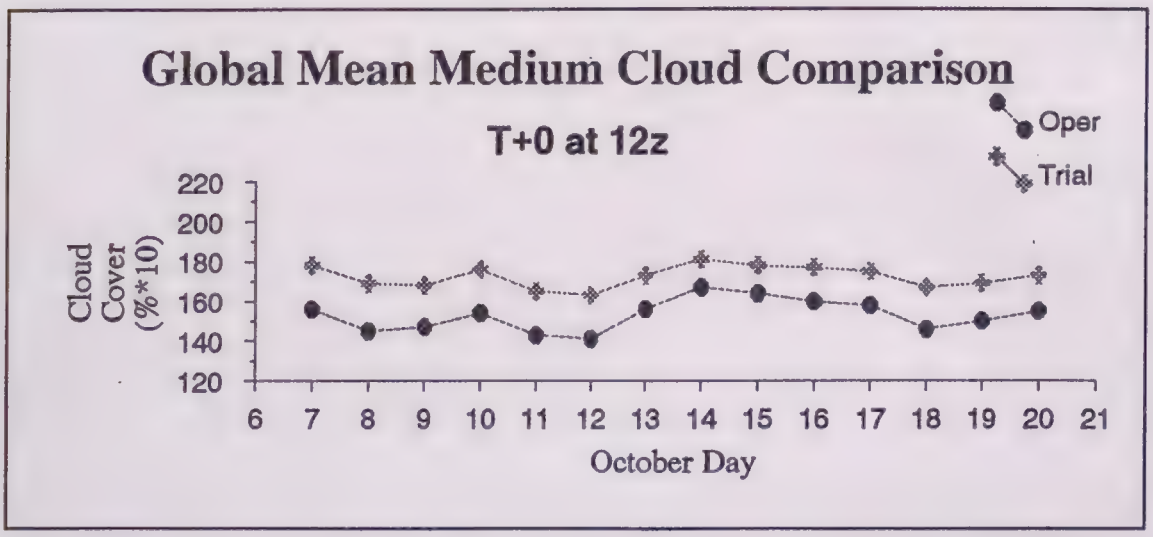

Global Mean RainRate
Trial
Rain Rate (mm/day *100)
350
320
290
260
230
200
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
October Day
T+0
T+24
T+48
T+72

FIGURE 1


Global Mean High Cloud Comparison
T+0 at 12z
Oper
Trial
Cloud Cover (%*10)
280
260
240
220
200
180
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
October Day


Global Mean Medium Cloud Comparison
T+0 at 12z
Oper
Trial
Cloud Cover (%*10)
220
200
180
160
140
120
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
October Day

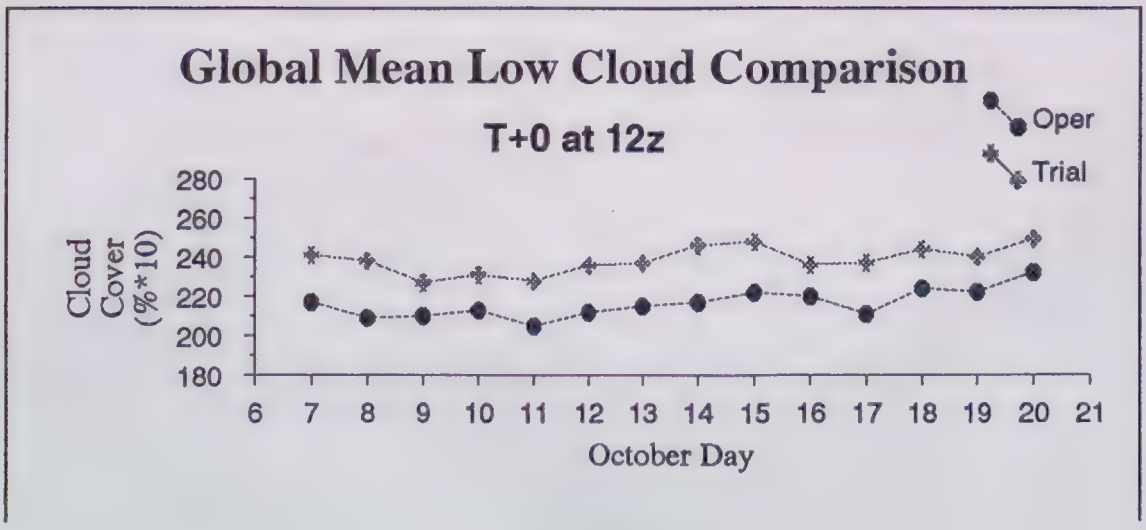

Global Mean Low Cloud Comparison
T+0 at 12z
Oper
Trial
Cloud Cover (%*10)
280
260
240
220
200
180
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
October Day

FIGURE 2

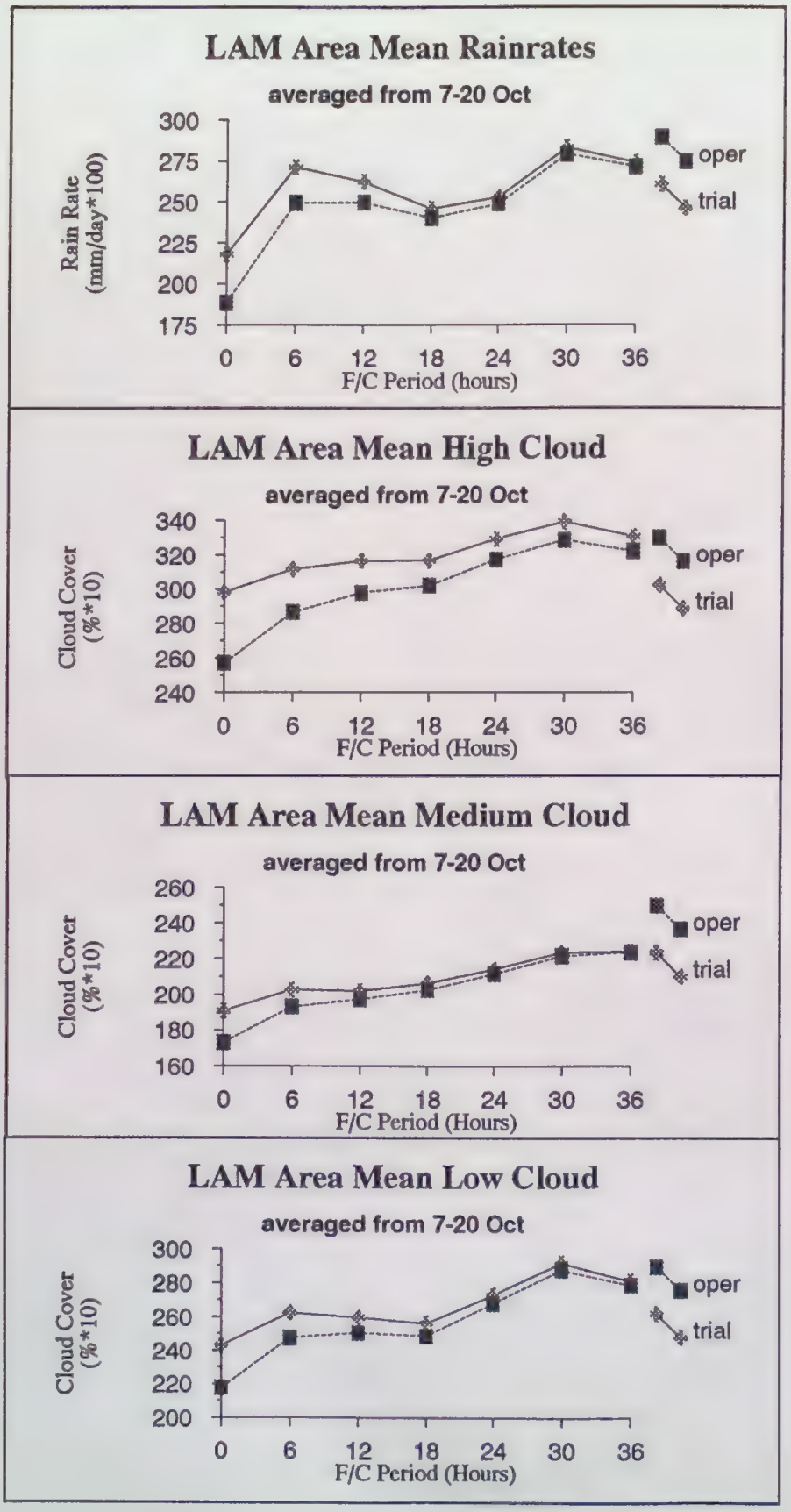

LAM Area Mean Rainrates
averaged from 7-20 Oct
Rain Rate (mm/day*100)
300
275
250
225
200
175
0 6 12 18 24 30 36
F/C Period (hours)
oper
trial
LAM Area Mean High Cloud
averaged from 7-20 Oct
Cloud Cover (%*10)
340
320
300
280
260
240
0 6 12 18 24 30 36
F/C Period (Hours)
oper
trial
LAM Area Mean Medium Cloud
averaged from 7-20 Oct
Cloud Cover (%*10)
260
240
220
200
180
160
0 6 12 18 24 30 36
F/C Period (Hours)
oper
trial
LAM Area Mean Low Cloud
averaged from 7-20 Oct
Cloud Cover (%*10)
300
280
260
240
220
200
0 6 12 18 24 30 36
F/C Period (Hours)
oper
trial

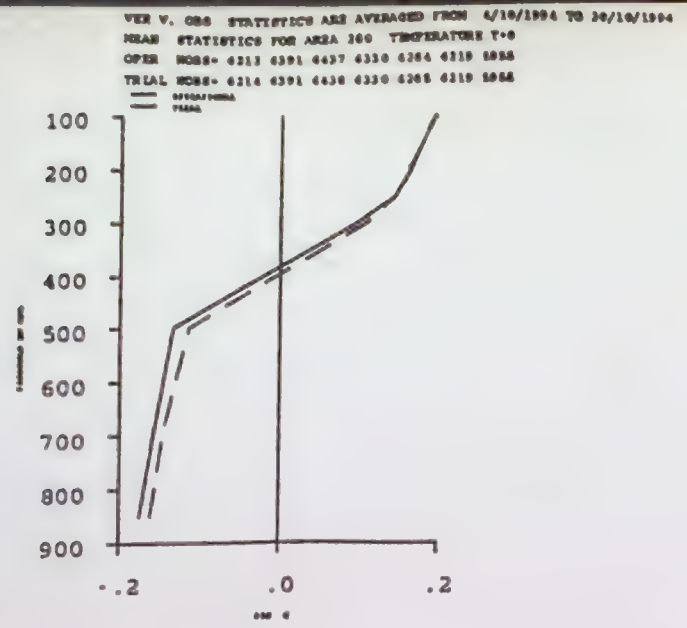
FIGURE 3

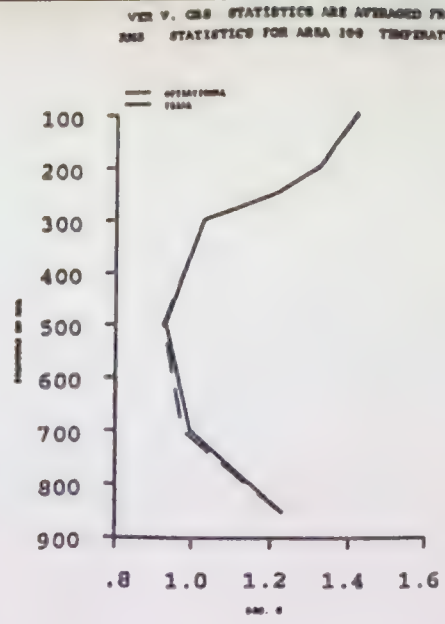
		AREA	2			AREA	200	
HEIGHTS	T+0	T+24	T+48	T+72	T+0	T+24	T+48	T+72
850	**101.4**	99.2	100.0	99.6	100.0	**98.9**	99.8	99.6
700	99.5	99.3	99.9	100.2	100.8	**98.2**	99.1	99.9
500	100.4	**98.5**	**98.1**	100.3	**98.9**	**97.7**	**98.2**	100.0
300	100.2	**97.4**	**98.4**	101.0	99.1	**96.6**	**97.8**	100.0
250	99.4	**96.6**	**98.3**	100.6	**98.8**	**96.1**	**97.6**	99.7
200	100.2	**96.0**	**98.5**	100.1	99.5	**96.5**	**98.3**	99.7
100	99.4	**96.6**	**98.2**	99.2	99.7	**97.2**	**98.3**	100.0
TEMPERATURES								
850	100.6	100.9	**98.5**	**98.1**	99.7	100.1	99.6	99.1
700	**98.7**	**98.6**	**97.8**	**101.4**	**98.1**	99.7	99.7	100.5
500	99.3	100.6	**98.5**	100.8	99.3	99.3	99.5	100.5
300	**101.2**	**98.5**	**98.9**	**98.8**	100.3	**97.4**	**97.8**	**98.2**
250	100.0	100.4	**98.8**	**98.9**	100.0	99.1	100.2	100.7
200	100.0	99.0	**97.5**	99.1	100.1	99.9	99.3	100.4
100	100.0	99.5	100.0	99.6	100.3	99.7	99.7	100.1
WINDS								
850	99.9	99.8	99.7	99.3	99.7	99.6	99.8	99.6
700	100.3	99.7	99.8	99.1	100.0	100.1	99.8	99.6
500	99.9	100.0	99.4	99.9	100.1	99.9	99.6	99.8
300	99.7	99.7	99.5	99.7	100.0	99.9	100.0	99.9
250	99.6	99.3	99.3	100.0	100.0	100.2	99.0	100.1
200	100.1	**98.9**	100.2	99.1	100.0	99.6	99.2	99.6
100	99.8	100.0	100.6	99.8	99.5	99.7	99.6	100.0
RH								
850	**98.9**	99.8	100.2	99.1	100.4	99.6	99.7	99.4
700	**95.7**	**101.2**	100.4	99.3	**96.2**	100.6	99.9	99.4
500	**96.1**	**101.1**	99.8	99.2	**97.2**	100.9	99.0	99.7
SURF								
pmsl	**98.4**	99.3	**101.2**	99.0	99.8	99.2	99.8	99.2
wind	99.8	100.1	99.5	**98.8**	100.1	100.0	99.7	99.0

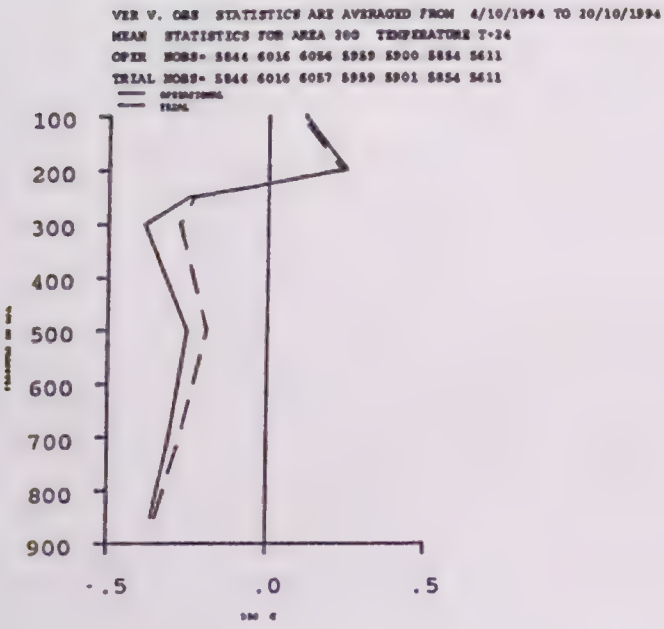
FIGURE 4

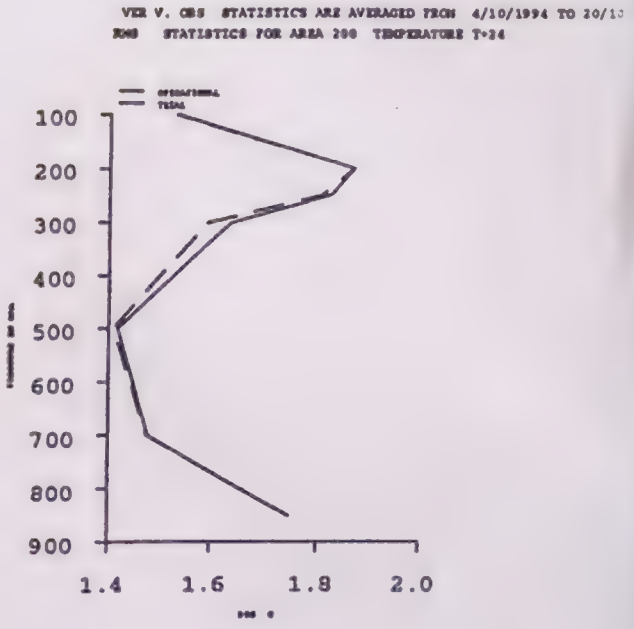
		AREA	300			AREA	400	
HEIGHTS	T+0	T+24	T+48	T+72	T+0	T+24	T+48	T+72
850	101.8	100.1	99.2	99.8	100.9	100.9	**102.4**	**101.1**
700	99.3	**96.2**	**97.6**	**97.9**	**98.9**	**101.1**	**101.6**	**101.3**
500	99.7	**97.7**	99.1	99.5	99.7	100.0	100.9	**101.0**
300	**98.7**	**95.7**	**96.6**	**97.7**	**98.3**	100.2	**101.7**	**102.3**
250	**98.6**	**94.8**	**95.8**	**97.3**	99.4	100.7	**102.5**	**102.0**
200	**98.7**	**95.3**	**97.0**	**97.7**	99.4	100.6	**101.4**	**101.1**
100	**98.8**	**95.2**	**96.7**	**97.9**	99.8	**98.4**	99.8	99.9
TEMPERATURES								
850	100.1	100.2	**101.9**	**101.2**	100.0	99.8	**101.2**	**101.0**
700	100.7	99.8	99.7	100.5	**102.4**	99.0	99.6	**103.0**
500	99.9	99.9	**98.4**	**97.6**	100.5	**103.9**	100.8	**103.2**
300	**98.3**	**94.1**	**95.2**	**96.6**	99.5	99.3	99.9	**101.1**
250	99.3	**98.2**	**101.7**	**104.4**	99.9	99.6	**97.6**	100.2
200	100.6	99.5	**98.5**	99.4	**98.6**	99.0	100.5	101.0
100	100.6	100.0	100.3	100.2	99.7	100.4	100.9	**101.4**
WINDS								
850	100.7	100.8	**101.9**	**101.7**	99.9	100.9	100.5	**101.0**
700	100.4	100.9	**101.4**	**101.4**	100.1	100.1	**98.6**	100.3
500	99.6	99.7	99.3	99.6	100.7	**102.3**	100.7	99.7
300	**101.6**	**101.8**	**101.9**	100.6	100.1	**101.8**	**102.5**	**101.4**
250	100.6	**101.3**	100.1	99.3	100.5	**104.2**	**104.0**	**102.4**
200	99.8	99.9	**98.6**	99.9	**98.1**	100.9	100.9	100.9
100	100.5	99.9	99.5	99.1	100.6	100.5	**101.4**	**101.1**
RH								
850	**101.3**	**101.5**	**101.2**	**101.1**	99.5	100.3	**98.8**	**98.5**
700	**97.6**	**101.3**	100.0	100.4	**93.4**	100.9	100.8	99.8
500	**97.4**	100.9	100.6	100.0	**98.4**	**101.4**	100.2	**105.4**
SURF								
pmsl	100.7	99.3	**98.6**	99.1	**98.8**	99.2	**101.3**	100.7
wind	100.5	100.7	100.0	99.9	99.8	100.1	100.5	100.2

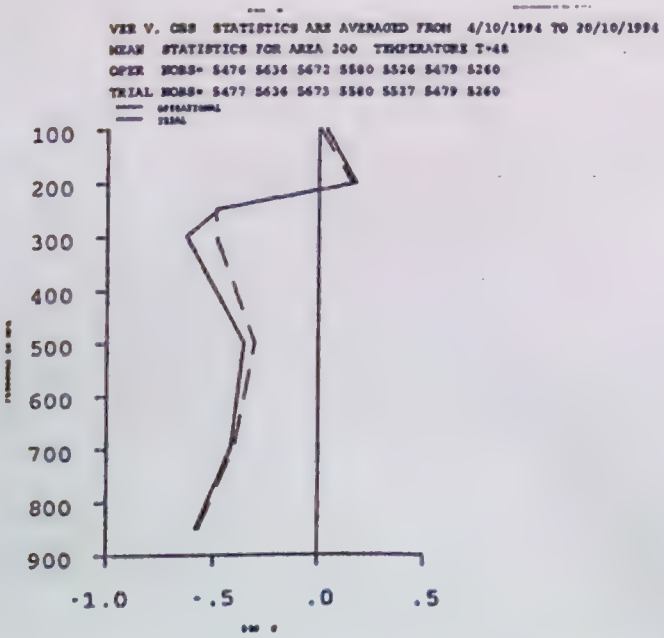
FIGURE 5


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+0
OPER NOBS= 6213 6391 6437 6330 6264 6219 5956
TRIAL NOBS= 6214 6391 6438 6330 6265 6219 5956
100
200
300
400
500
600
700
800
900
-.2
.0
.2


100
200
300
400
500
600
700
800
900
.8
1.0
1.2
1.4
1.6


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+24
OPER NOBS= 5844 6016 6056 5959 5900 5854 5611
TRIAL NOBS= 5846 6016 6057 5959 5901 5854 5611
100
200
300
400
500
600
700
800
900
-.5
.0
.5


100
200
300
400
500
600
700
800
900
1.4
1.6
1.8
2.0


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 200 TEMPERATURE T+48
OPER NOBS= 5476 5636 5672 5580 5526 5479 5260
TRIAL NOBS= 5477 5636 5673 5580 5527 5479 5260
100
200
300
400
500
600
700
800
900
-1.0
-.5
.0
.5

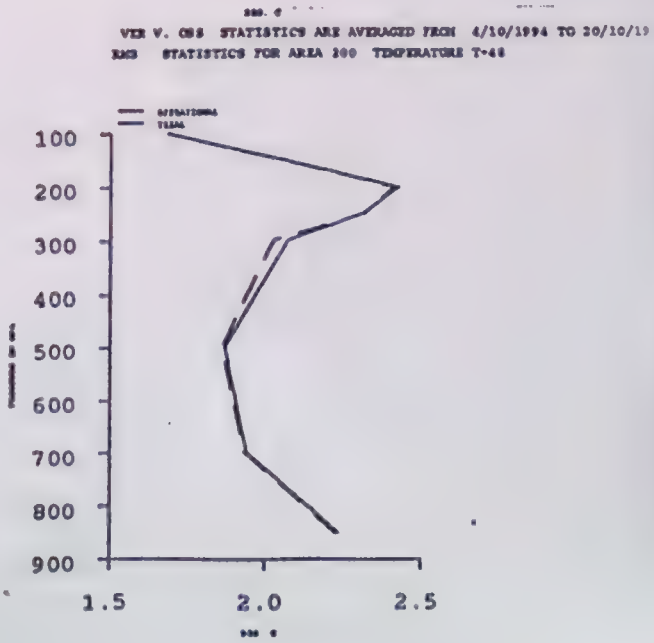
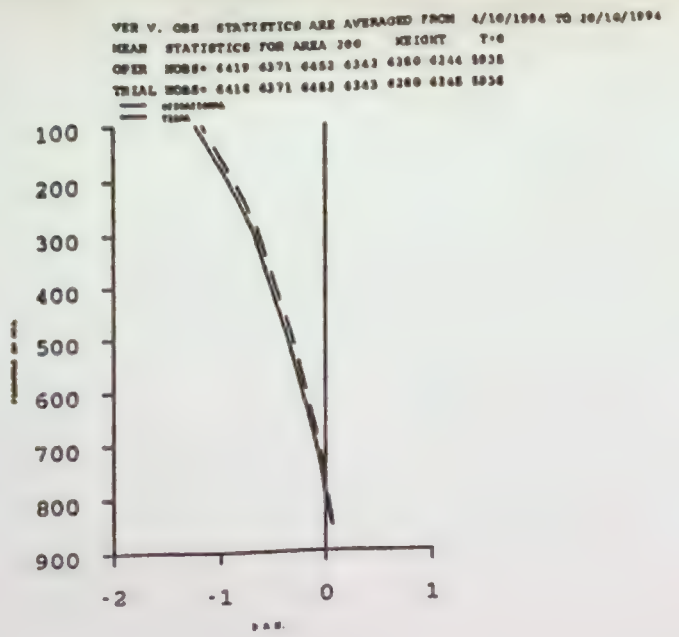
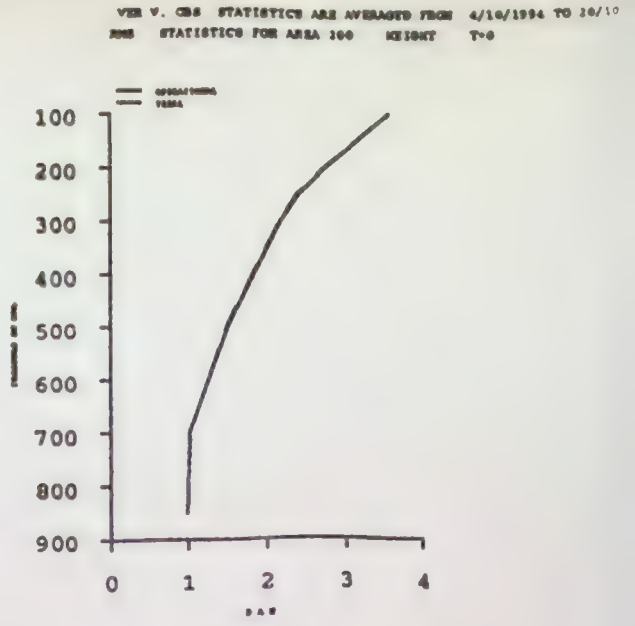
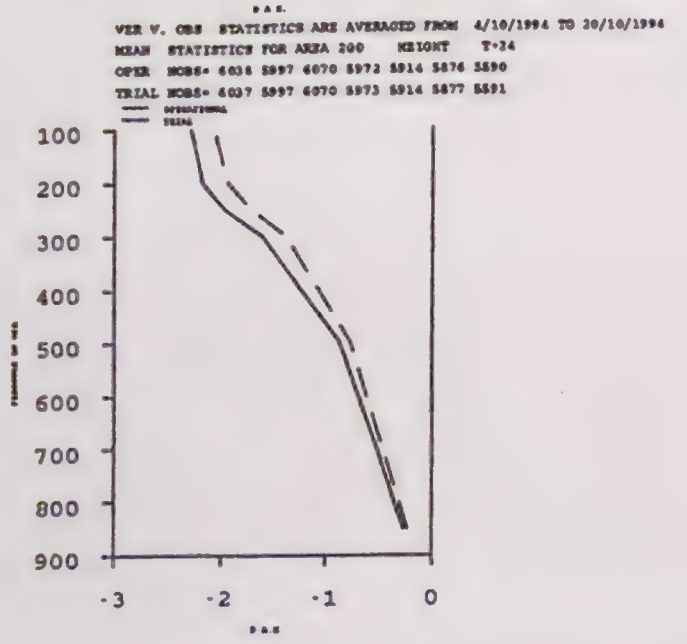
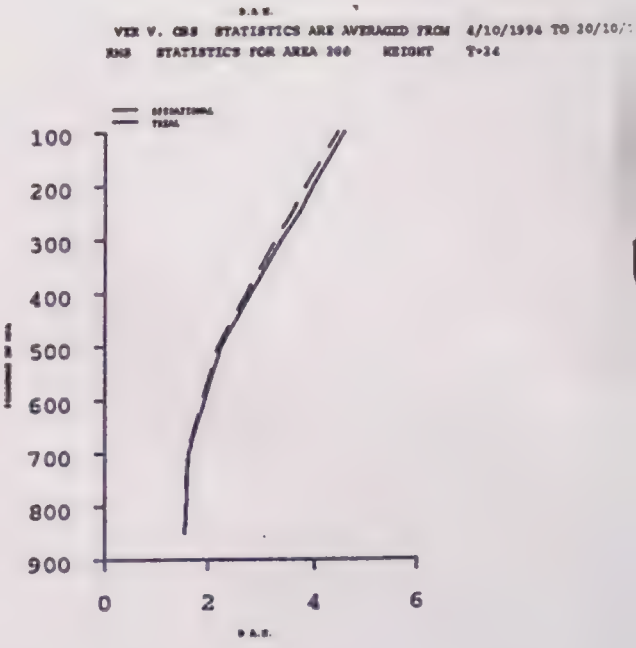

100
200
300
400
500
600
700
800
900
1.5
2.0
2.5

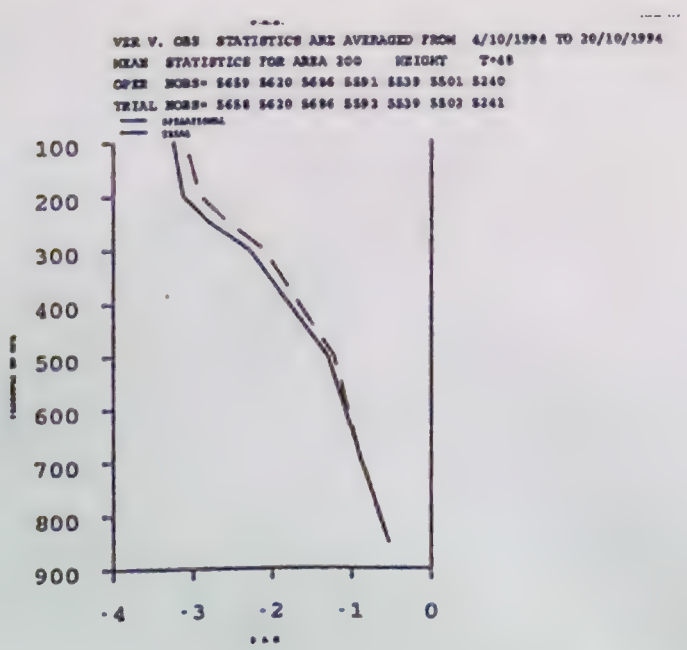
FIGURE 6


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 200 HEIGHT T+0
OPER MOBS= 6419 6371 6452 6363 6260 6244 5936
TRIAL MOBS= 6416 6371 6452 6363 6260 6245 5936
100
200
300
400
500
600
700
800
900
-2
-1
0
1


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10
RMS STATISTICS FOR AREA 200 HEIGHT T+0
100
200
300
400
500
600
700
800
900
0
1
2
3
4


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 200 HEIGHT T+24
OPER MOBS= 6036 5997 6070 5972 5914 5876 5590
TRIAL MOBS= 6037 5997 6070 5973 5914 5877 5591
100
200
300
400
500
600
700
800
900
-3
-2
-1
0


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/
RMS STATISTICS FOR AREA 200 HEIGHT T+24
100
200
300
400
500
600
700
800
900
0
2
4
6


VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 200 HEIGHT T+48
OPER MOBS= 5659 5620 5696 5591 5539 5501 5240
TRIAL MOBS= 5658 5620 5696 5593 5539 5502 5241
100
200
300
400
500
600
700
800
900
-4
-3
-2
-1
0

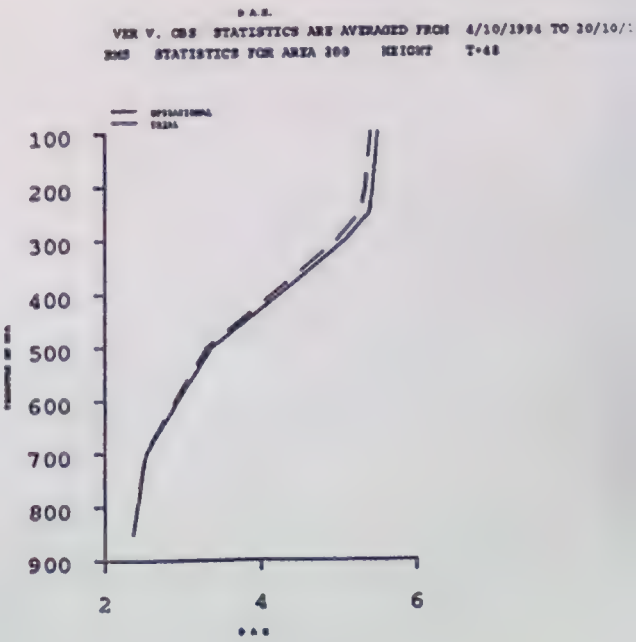

VER V. OBS STATISTICS ARE AVERAGED FROM 4/10/1994 TO 20/10/
RMS STATISTICS FOR AREA 200 HEIGHT T+48
100
200
300
400
500
600
700
800
900
2
4
6

FIGURE 7

		AREA	5		AREA	88
HEIGHTS		0	24		0	24
850		100.0	**102.0**		100.0	**102.1**
500		100.2	**95.5**		**98.4**	**98.3**
300		**98.3**	**91.9**		**98.1**	**96.4**
250		99.3	**92.4**		100.0	**96.0**
200		99.3	**92.7**		99.9	**95.4**
100		99.5	**96.6**		99.6	**97.4**
TEMPERATURES						
850		**97.8**	**98.6**		99.0	**97.7**
500		100.0	99.0		**101.5**	99.9
300		**102.8**	**96.0**		100.0	**97.8**
250		**98.3**	**96.9**		101.0	99.0
200		101.0	**97.1**		**96.9**	99.5
100		100.0	99.6		100.0	100.1
WINDS						
850		**101.3**	100.5		100.2	99.8
500		100.5	99.2		100.4	100.7
300		99.5	99.3		100.5	100.9
250		99.1	**97.1**		100.0	100.1
200		100.0	99.8		100.0	100.9
100		100.5	100.0		100.3	100.7
RH						
850		**96.0**	**96.3**		99.2	**97.6**
700		**93.5**	**103.0**		**91.1**	99.8
500		**95.6**	**103.5**		**92.0**	100.5
SURFACE						
pmsl		**101.4**	101.0		100.1	99.0
temp		100.9	**101.1**		99.2	99.1
wind		100.1	100.5		100.3	99.9

FIGURE 8

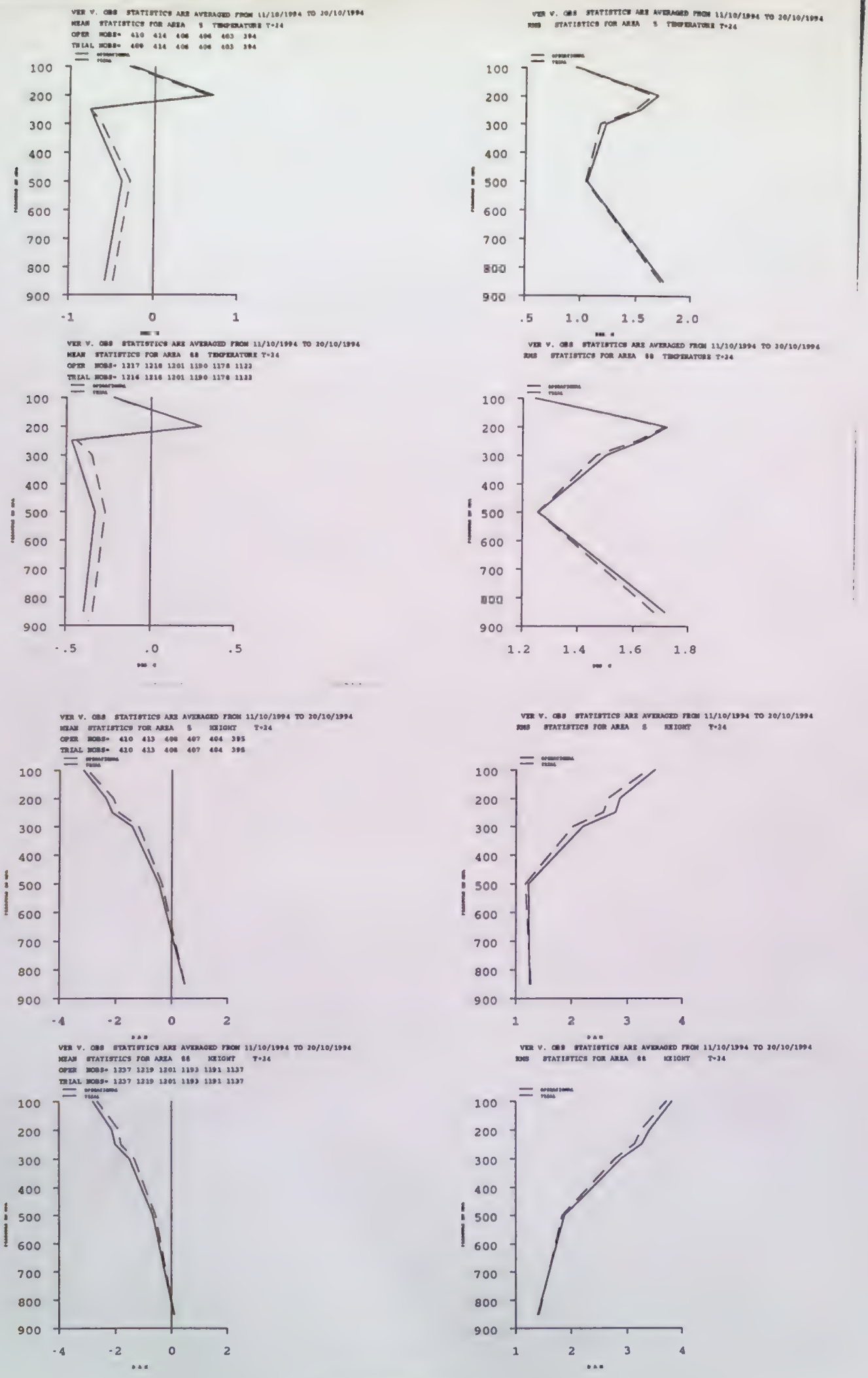
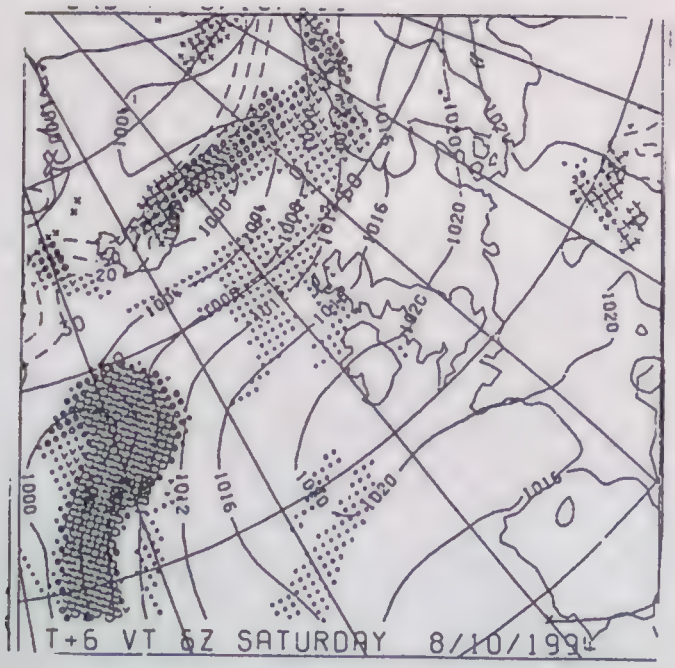
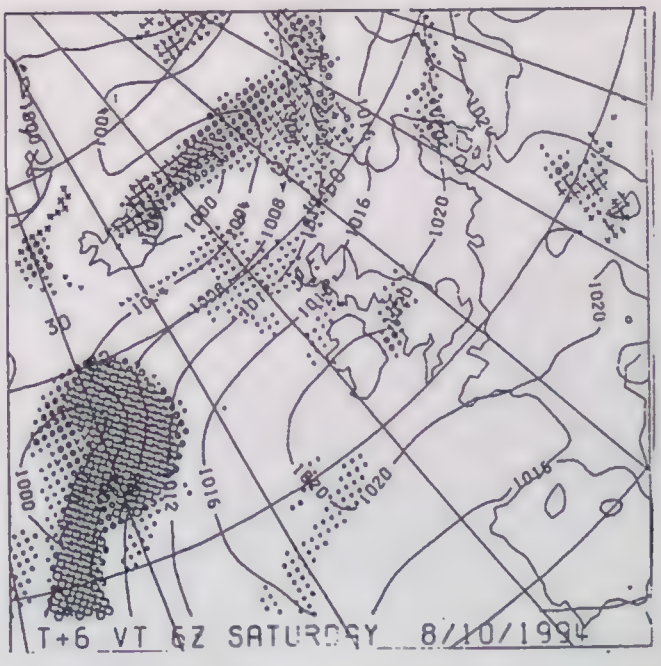

VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 5 TEMPERATURE T+24
OPER MOBS= 410 414 406 406 403 394
TRIAL MOBS= 409 414 406 406 403 394
100
200
300
400
500
600
700
800
900
-1
0
1
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
RMS STATISTICS FOR AREA 5 TEMPERATURE T+24
.5
1.0
1.5
2.0
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 88 TEMPERATURE T+24
OPER MOBS= 1217 1210 1201 1190 1178 1123
TRIAL MOBS= 1216 1210 1201 1190 1178 1123
-.5
.0
.5
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
RMS STATISTICS FOR AREA 88 TEMPERATURE T+24
1.2
1.4
1.6
1.8
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 5 HEIGHT T+24
OPER MOBS= 410 413 408 407 404 395
TRIAL MOBS= 410 413 408 407 404 395
-4
-2
0
2
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
RMS STATISTICS FOR AREA 5 HEIGHT T+24
1
2
3
4
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
MEAN STATISTICS FOR AREA 88 HEIGHT T+24
OPER MOBS= 1237 1219 1201 1193 1191 1137
TRIAL MOBS= 1237 1219 1201 1193 1191 1137
VER V. OBS STATISTICS ARE AVERAGED FROM 11/10/1994 TO 20/10/1994
RMS STATISTICS FOR AREA 88 HEIGHT T+24

FIGURE 9

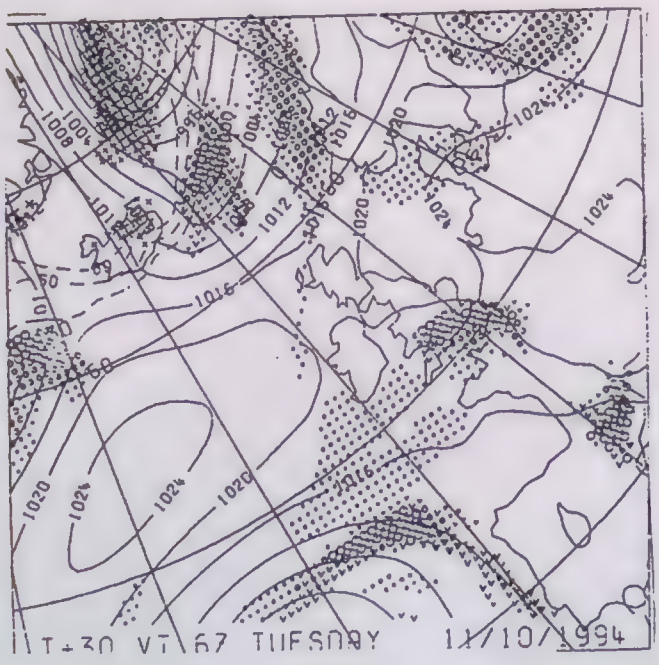


OPER

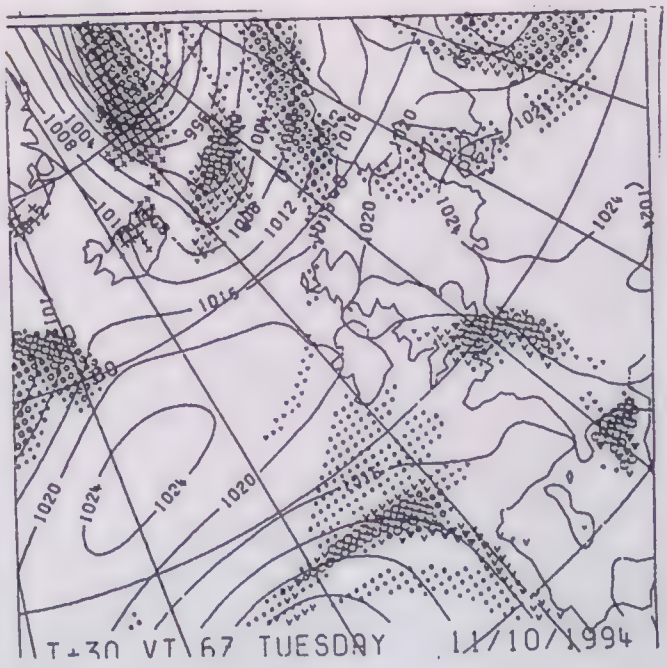


TRIAL

FIGURE 10

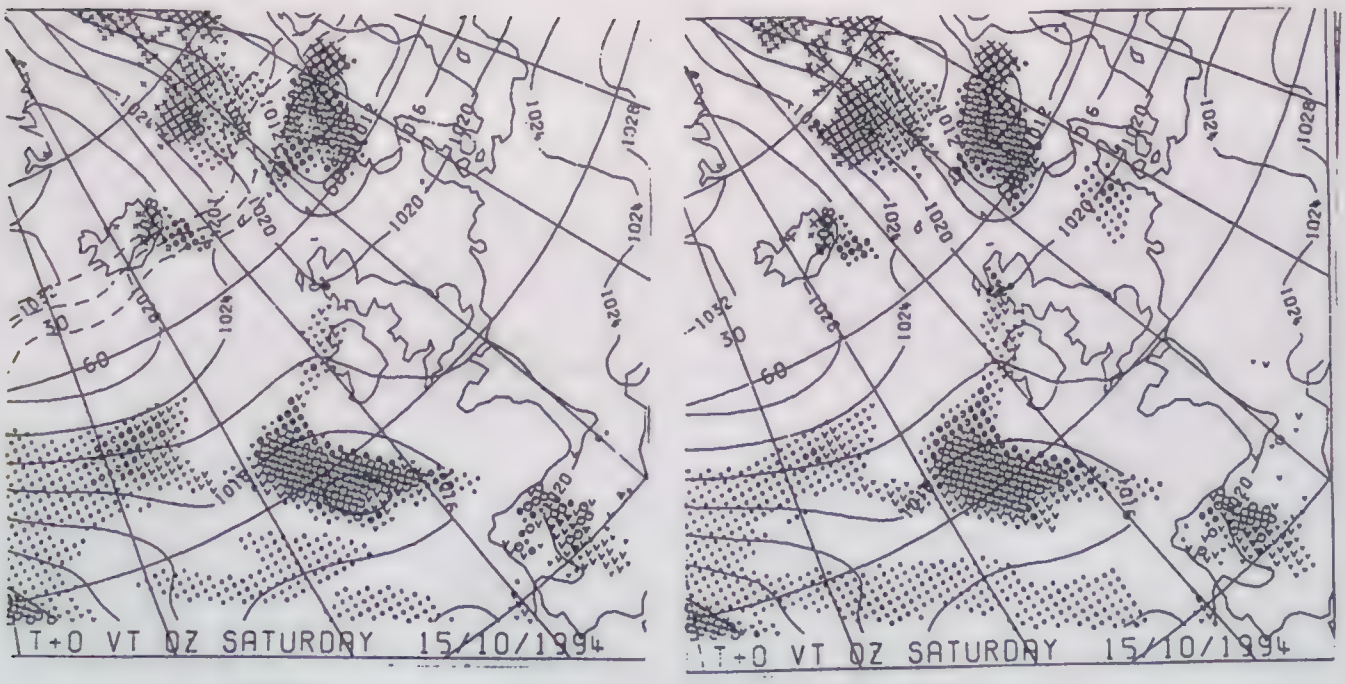


OPER



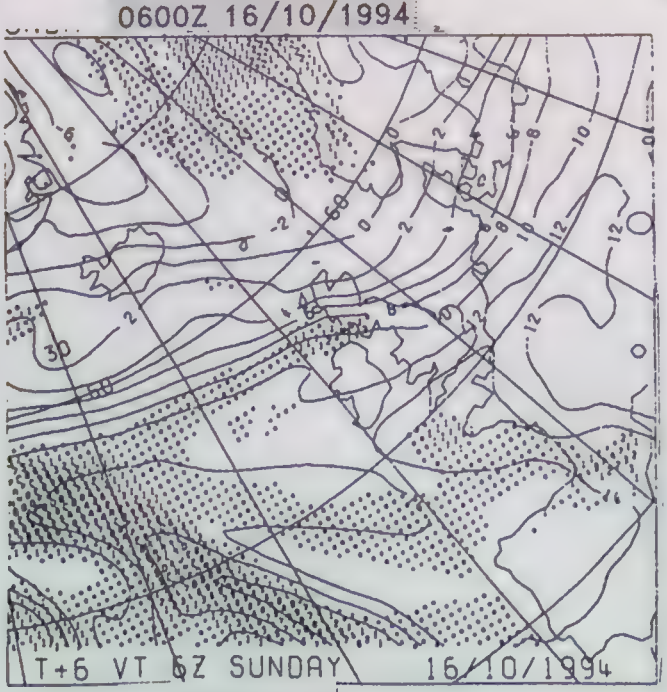
TRIAL

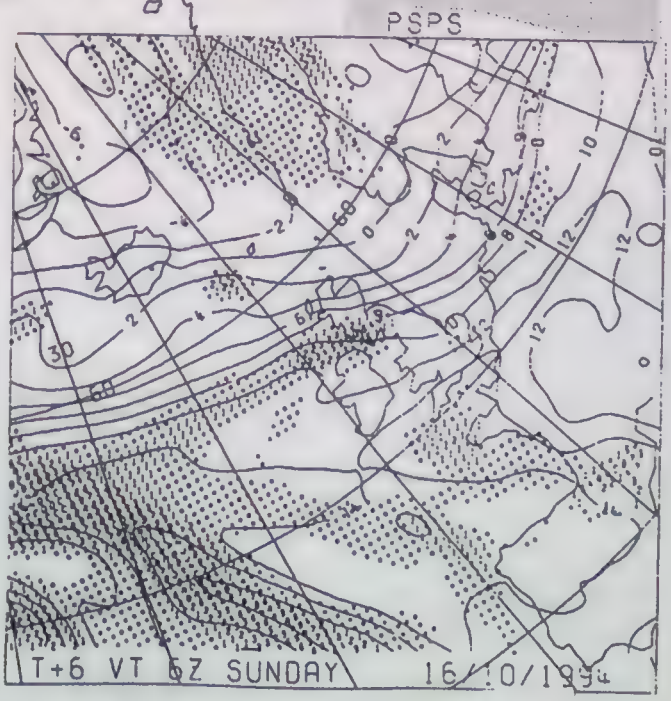
FIGURE 11



OPER **TRIAL**

FIGURE 12

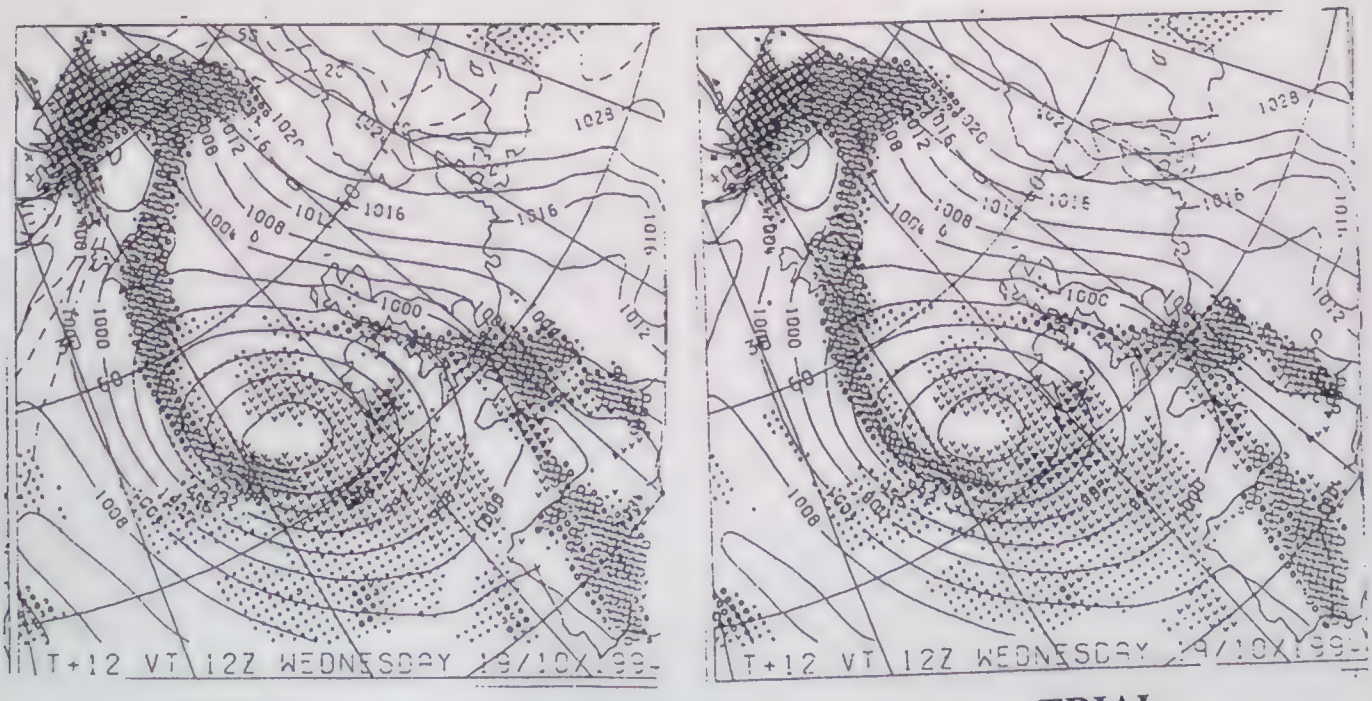




OPER

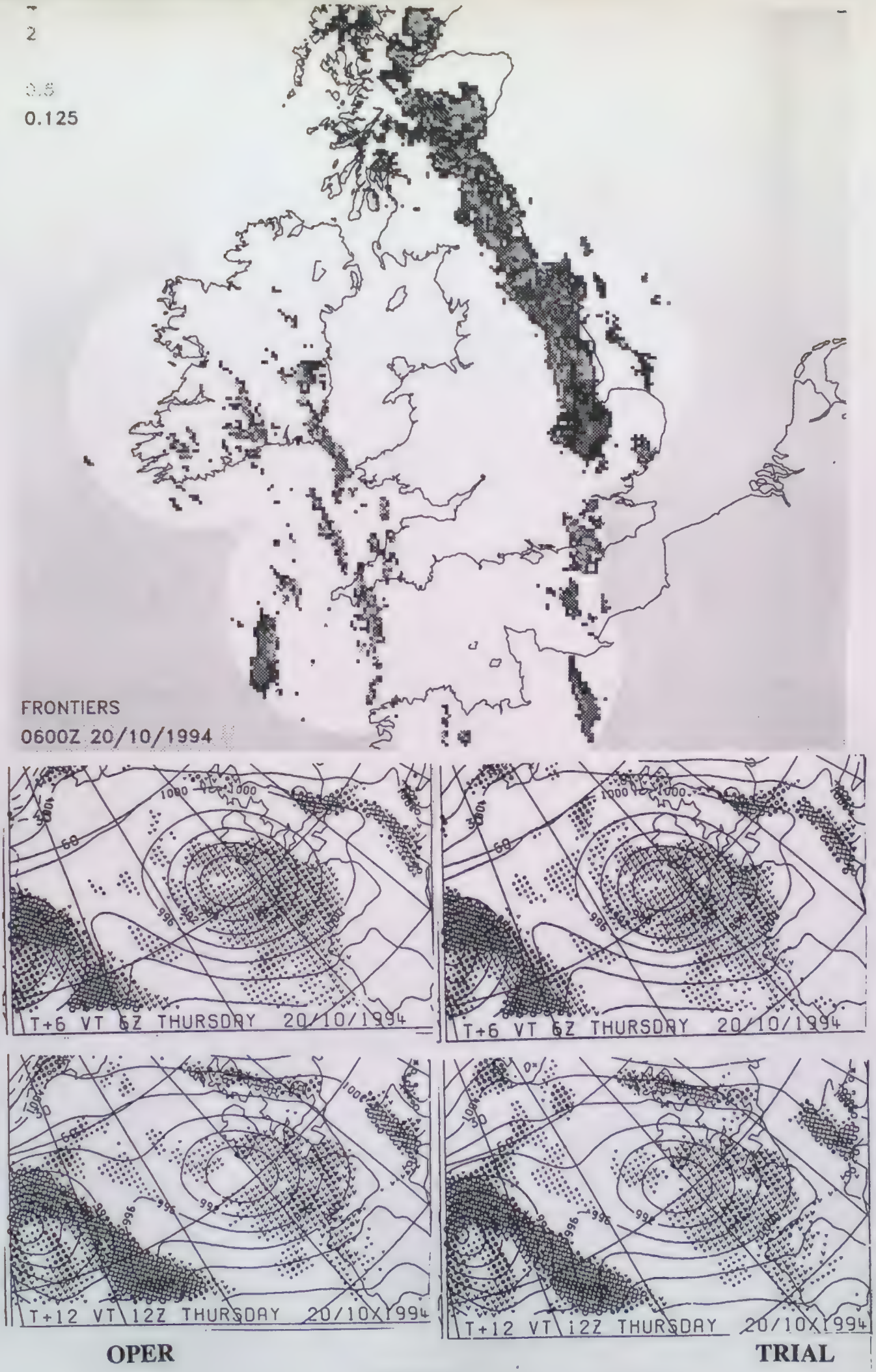
FIGURE 13

TRIAL



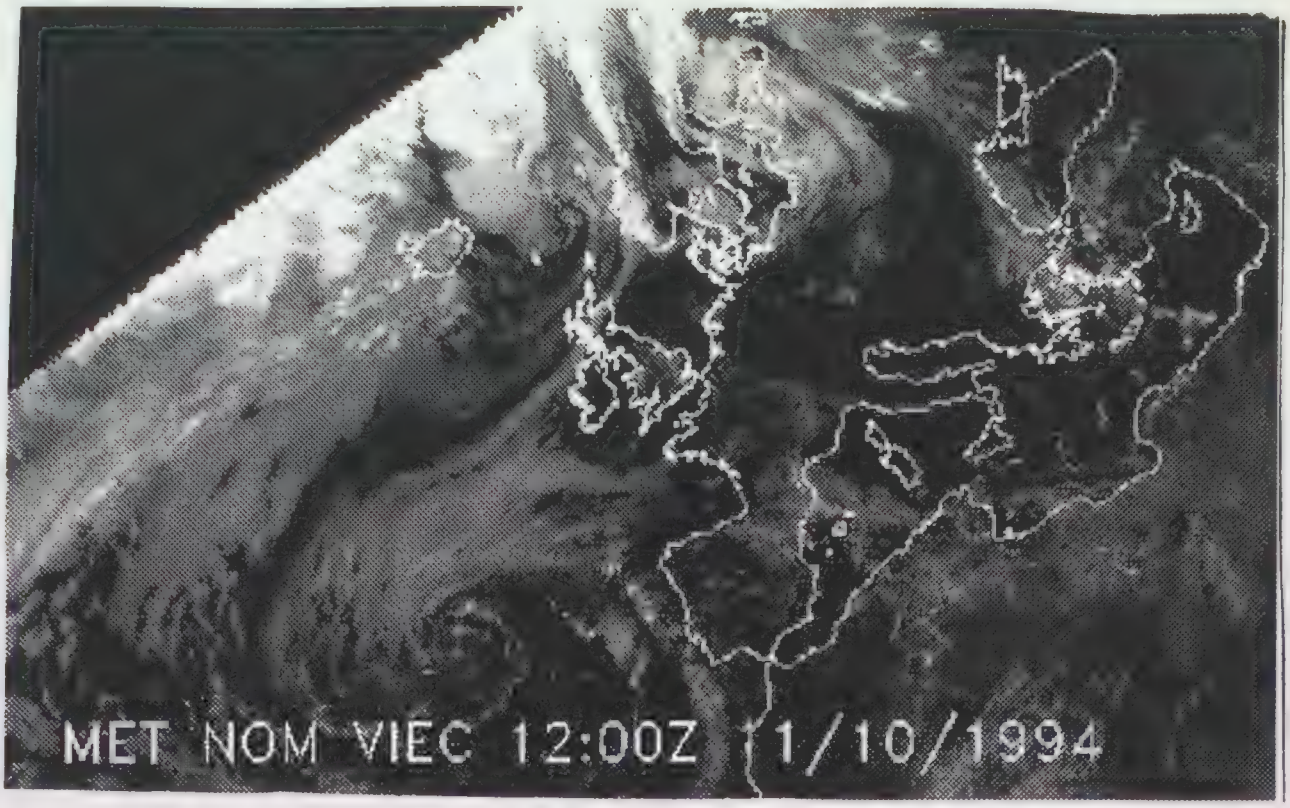
OPER TRIAL

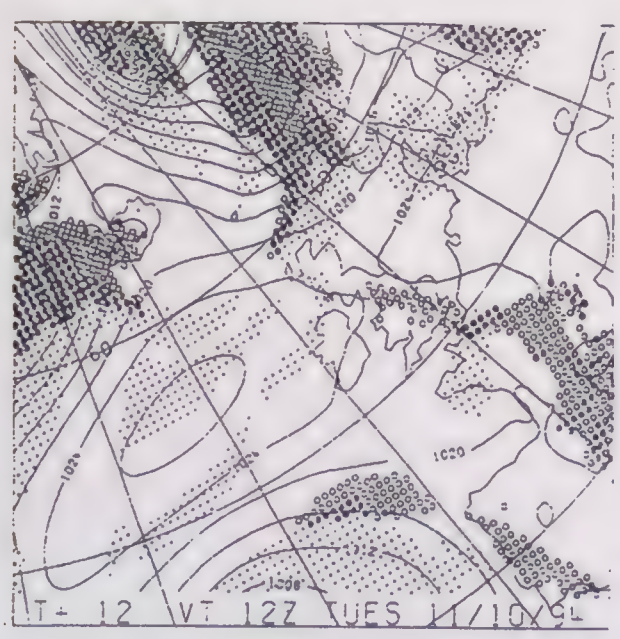
FIGURE 14



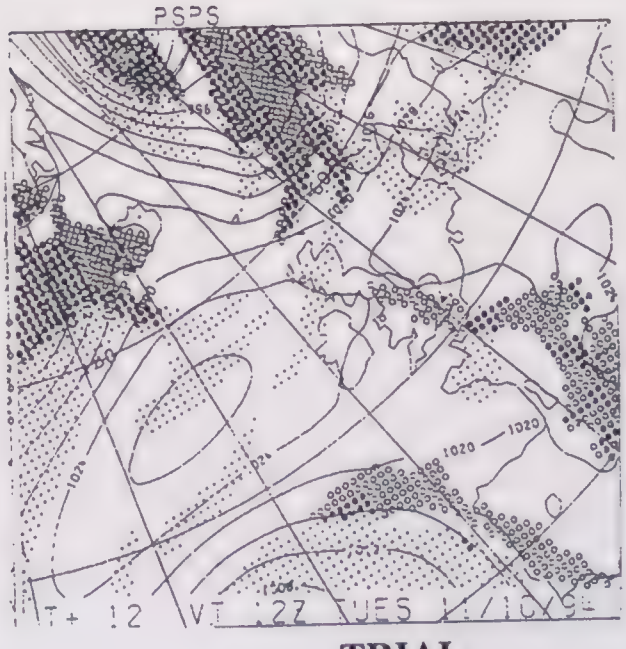
OPER **TRIAL**

FIGURE 15



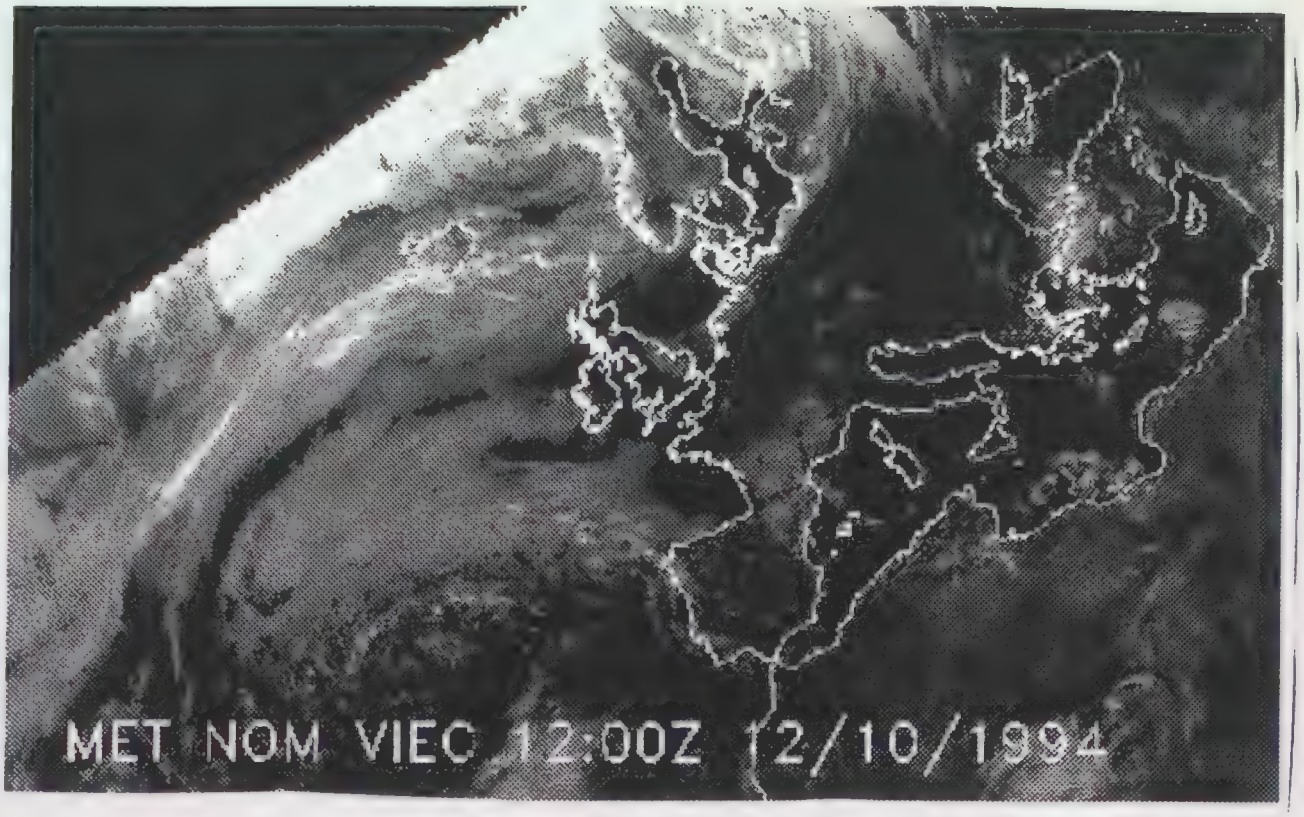


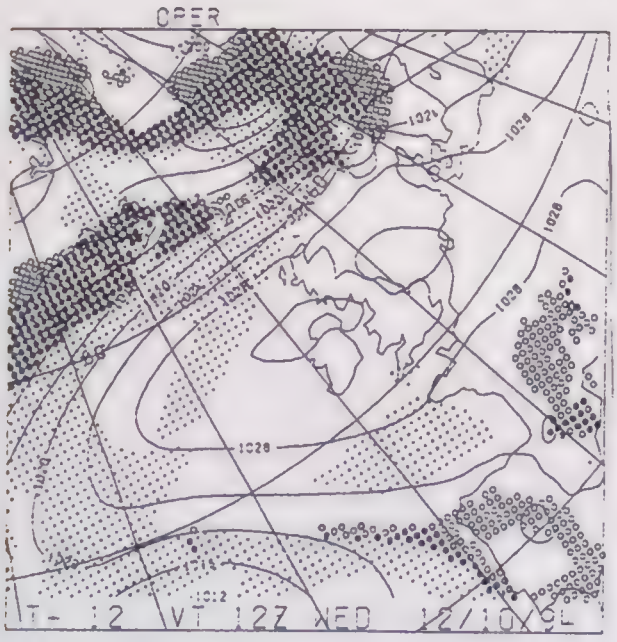
OPER



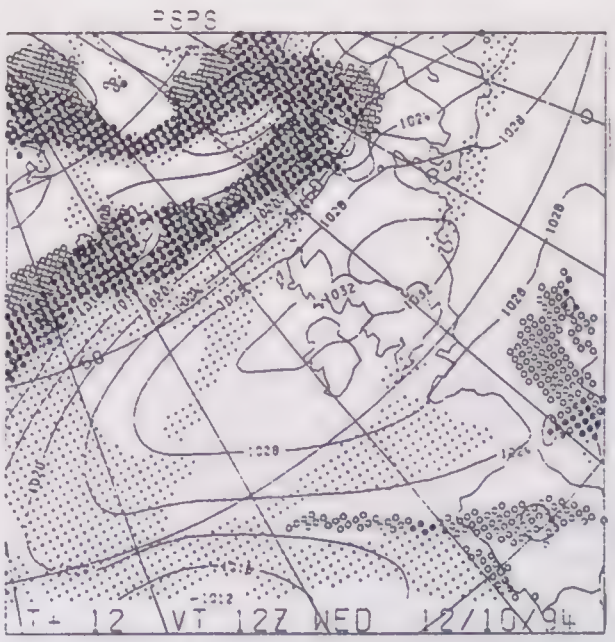
TRIAL

FIGURE 16



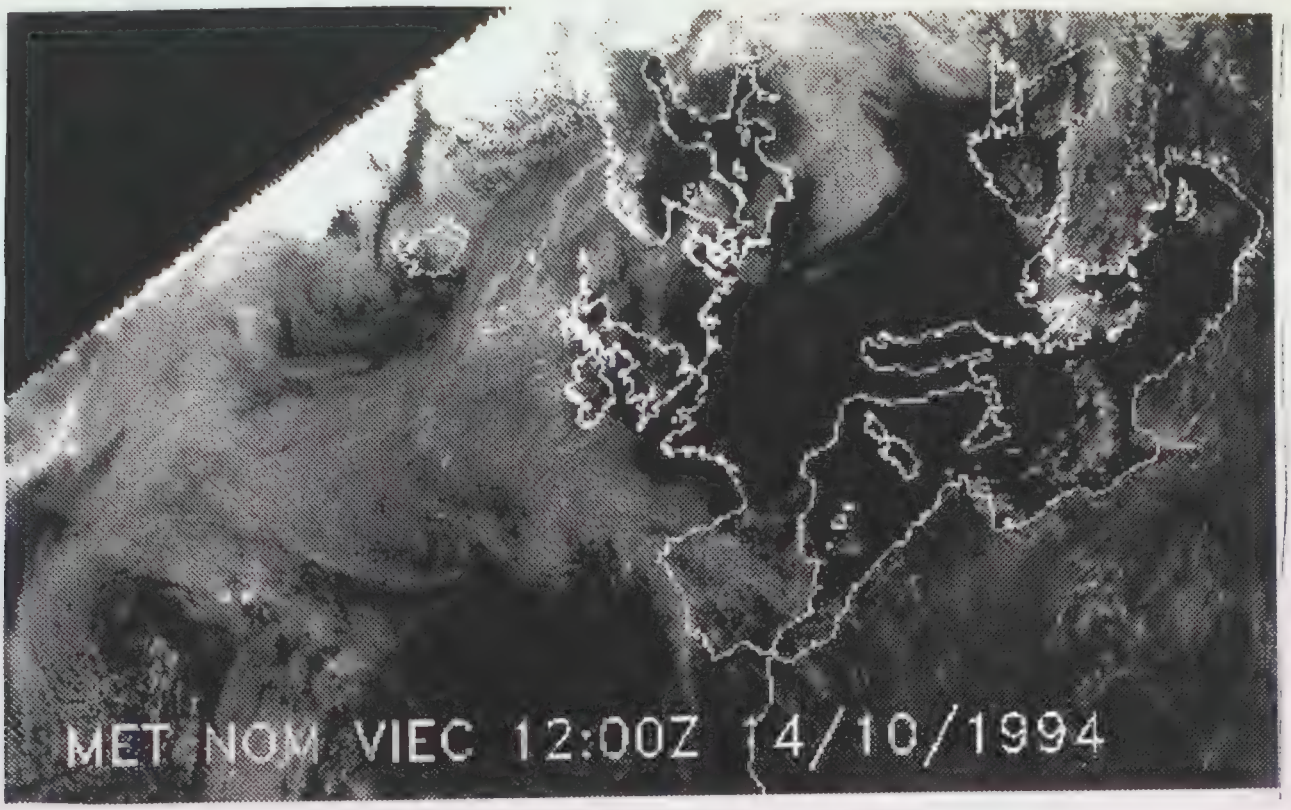


OPER

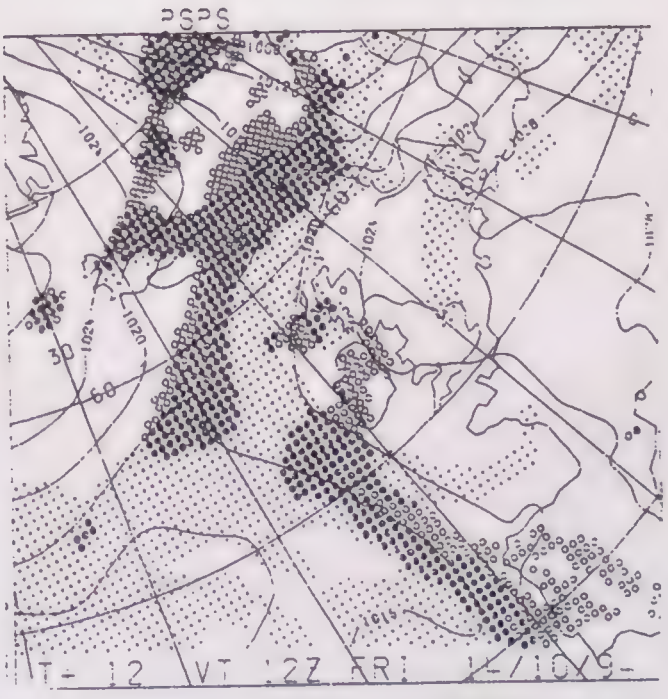


TRIAL

FIGURE 17

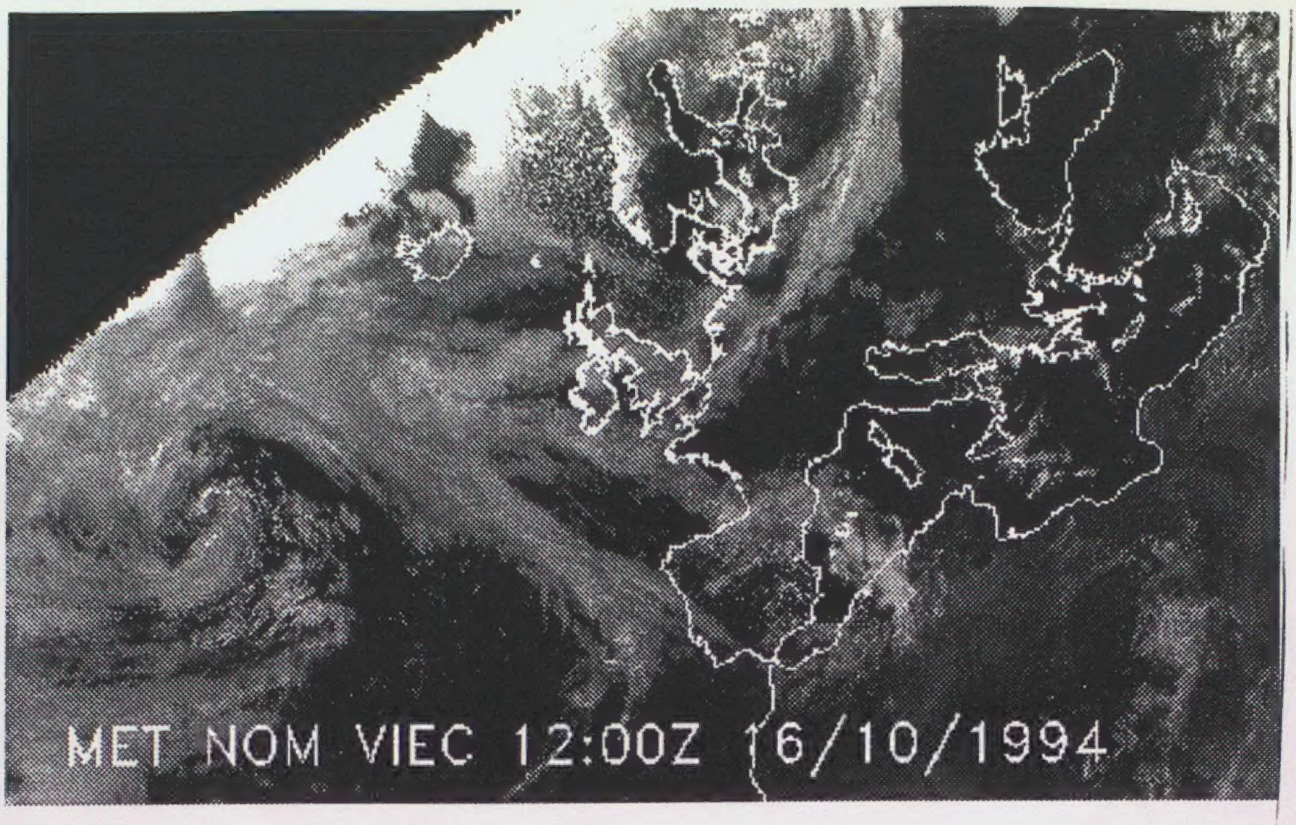


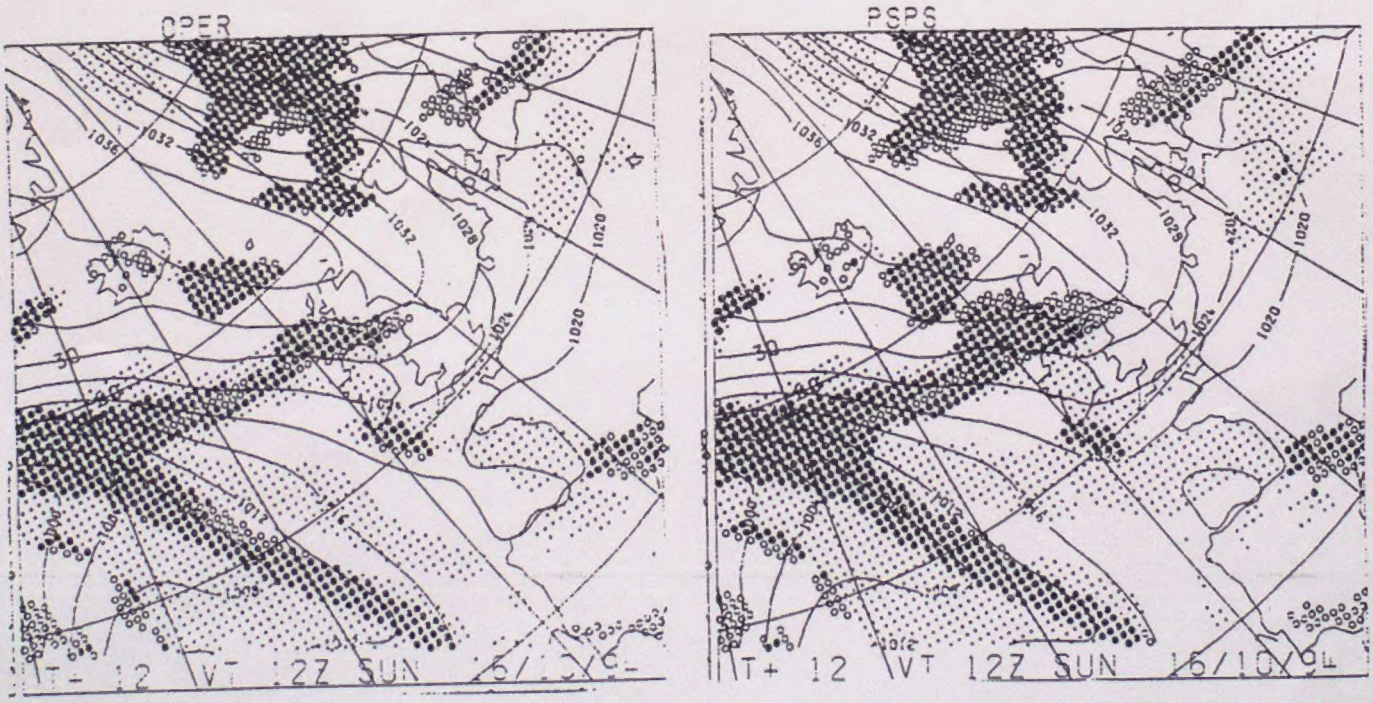
OPER



TRIAL

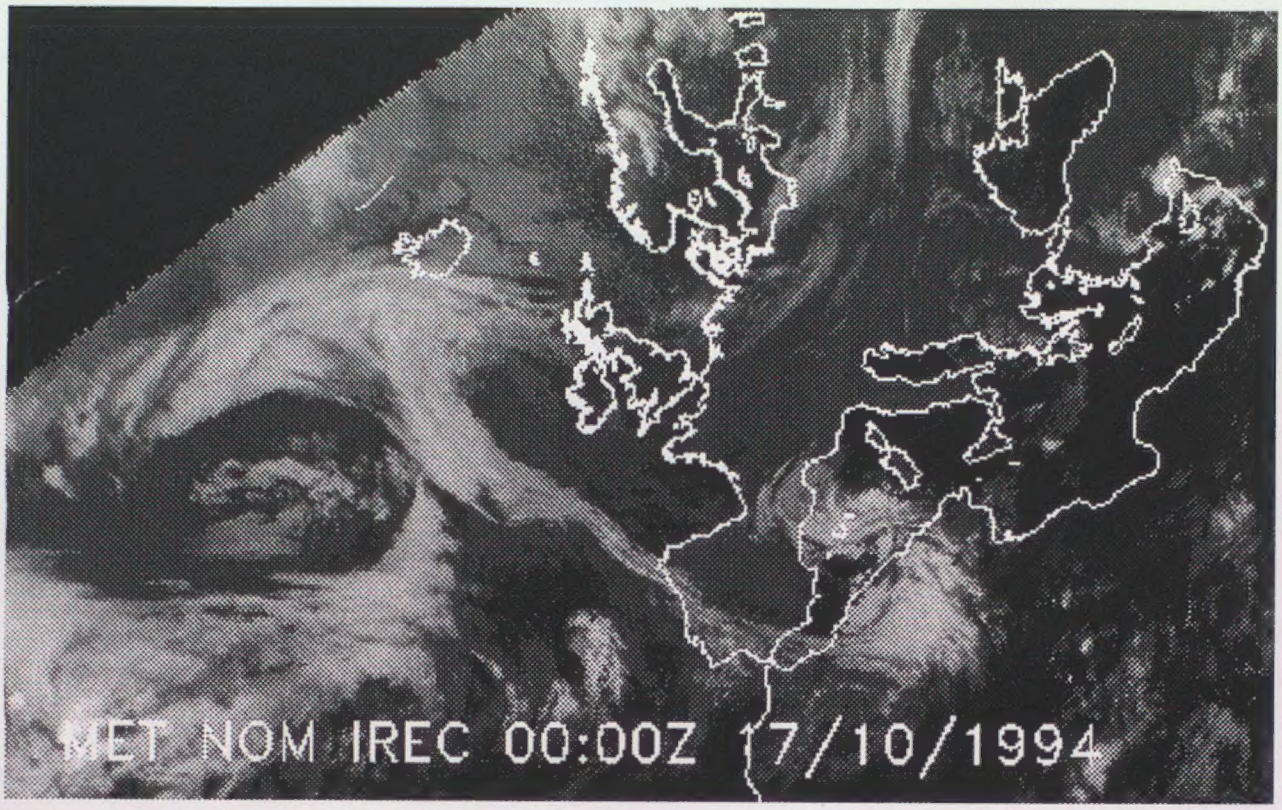
FIGURE 18

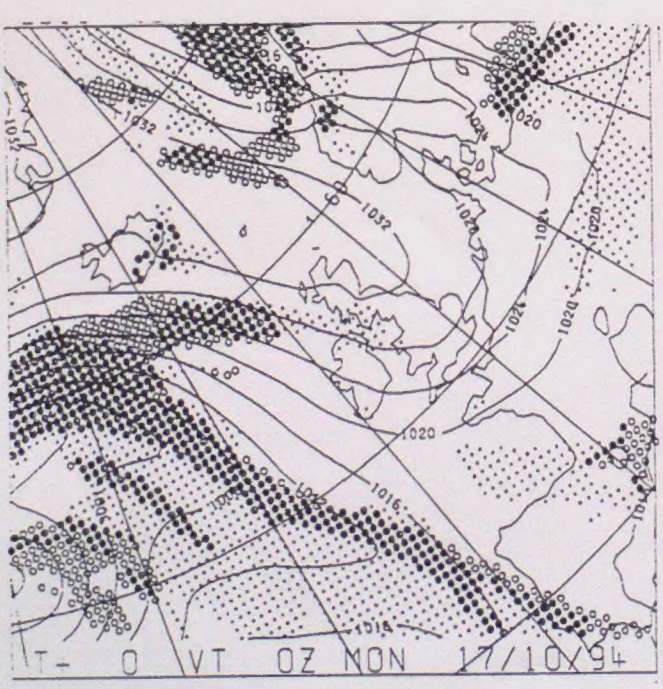




OPER **TRIAL**

FIGURE 19





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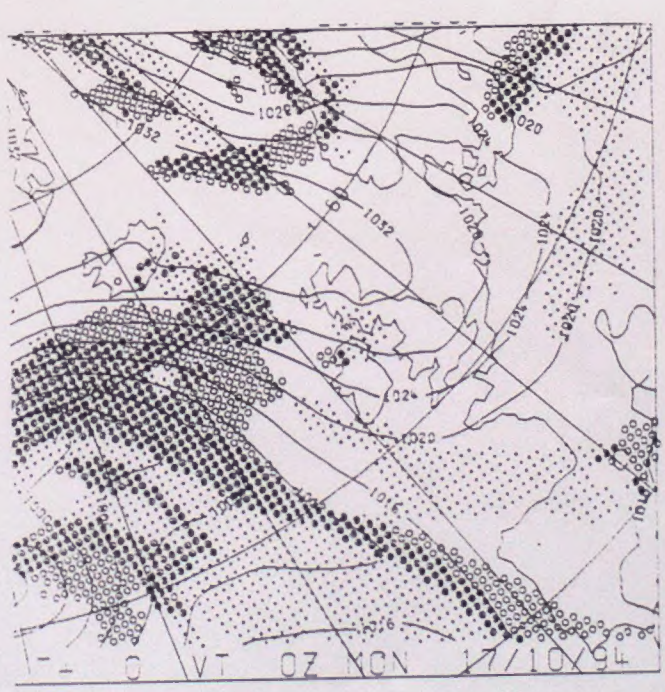

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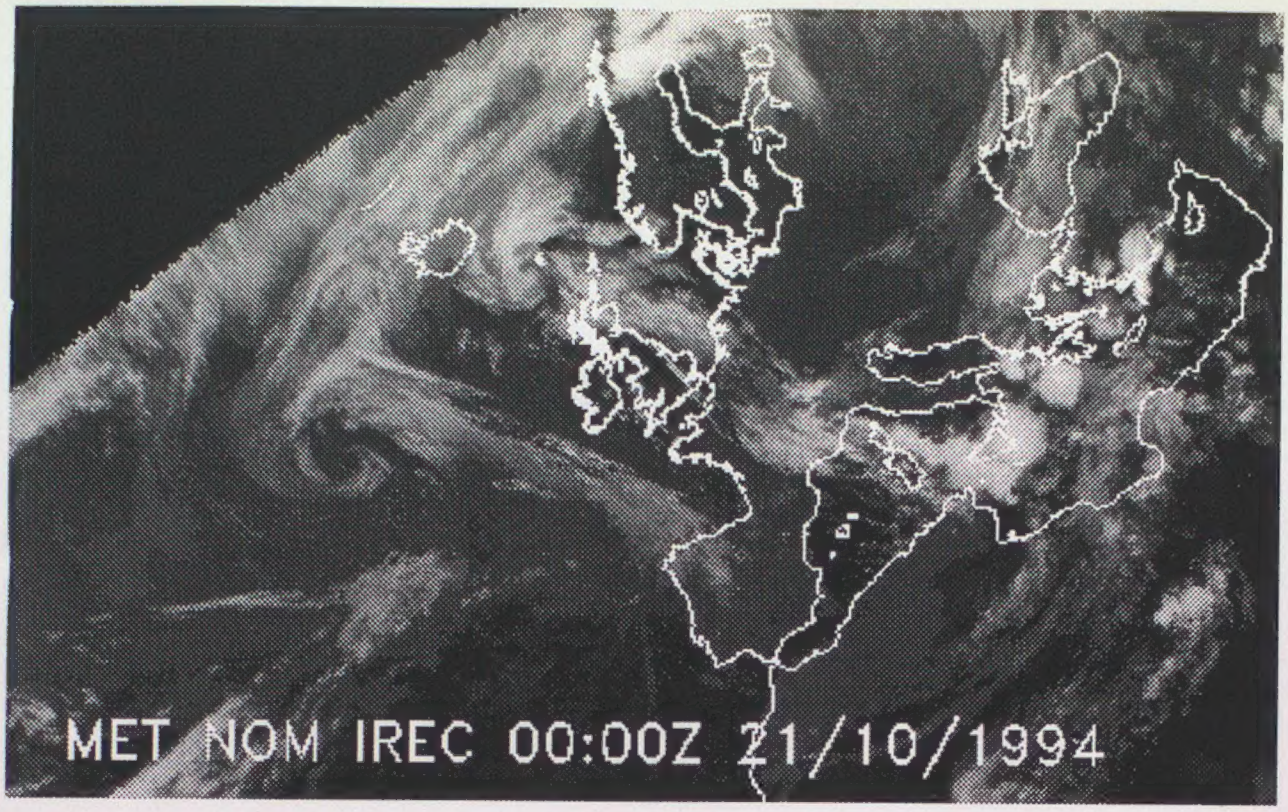
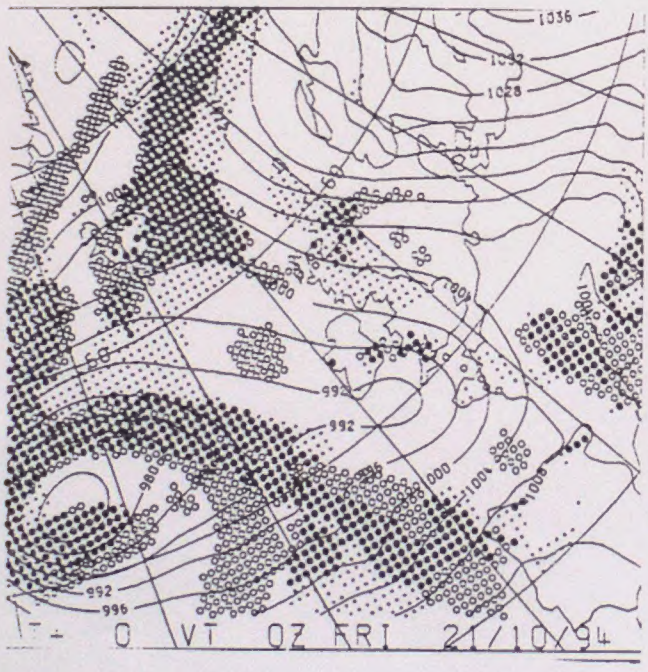
FIGURE 20





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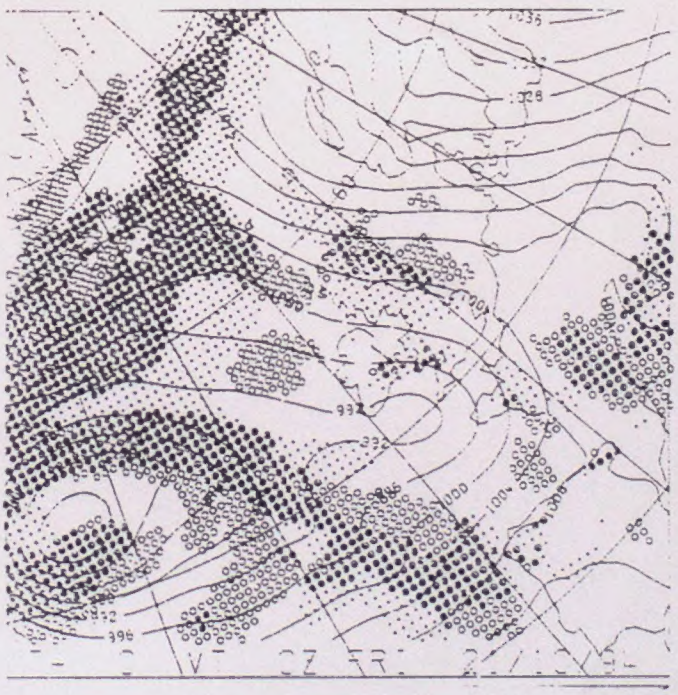

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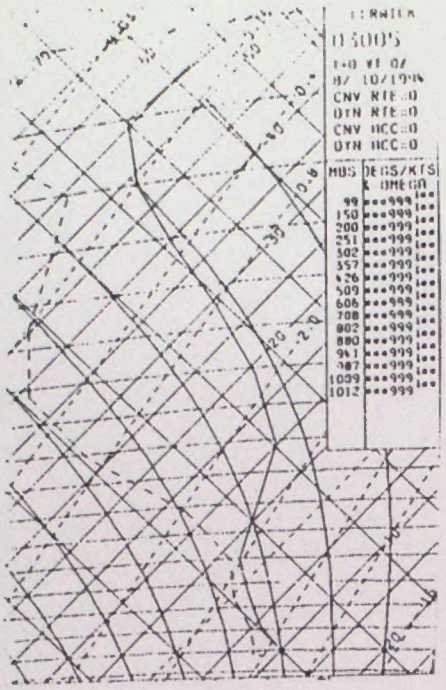
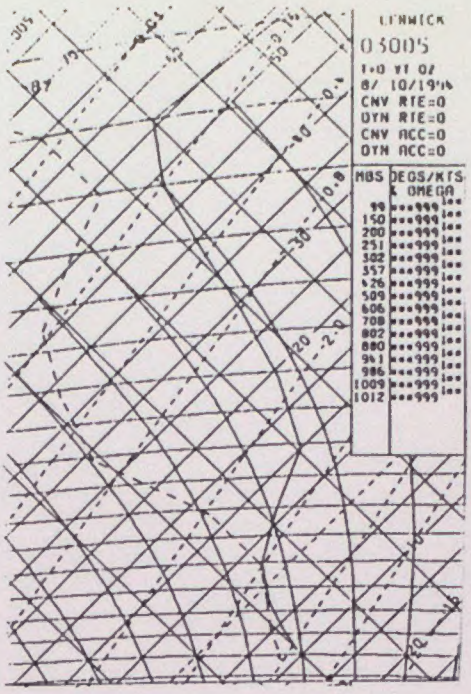
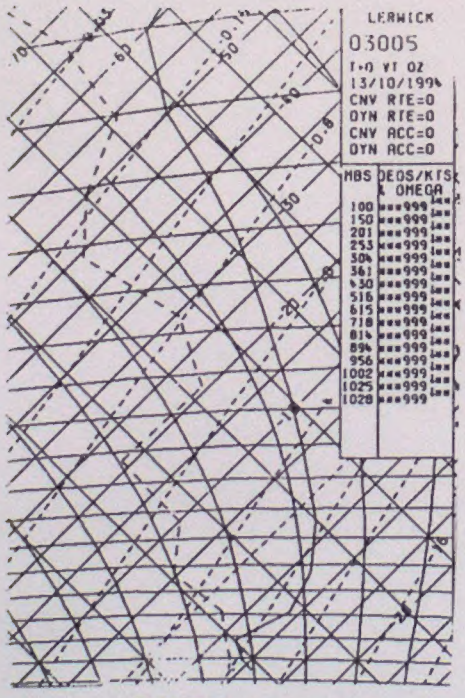
FIGURE 21







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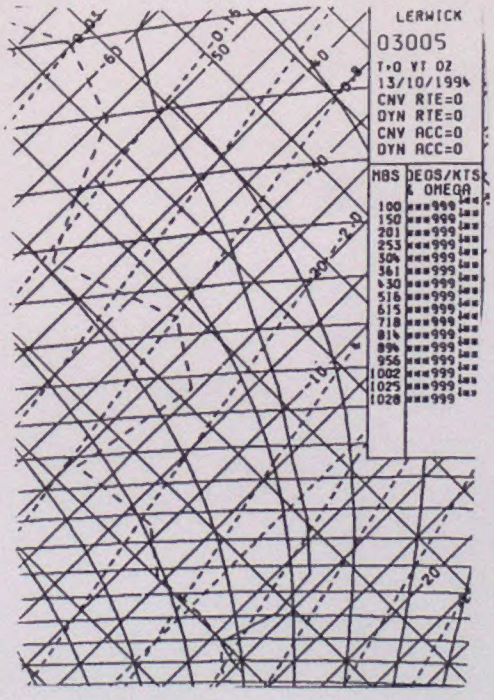

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FIGURE 22